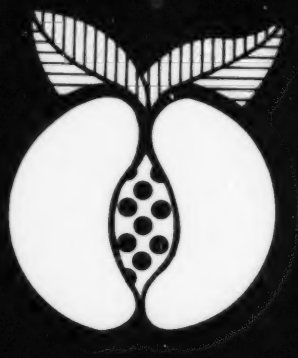
Curriculum Ideas
for Teachers

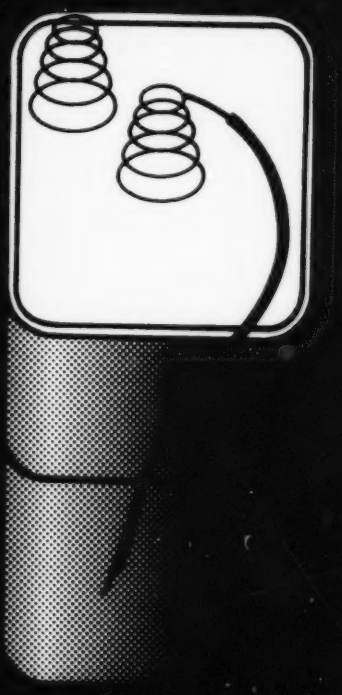
1983

Science in the Primary and Junior Divisions

Science

A Source Book





87-01403/

This document was developed for the Ministry of Education by the University of Western Ontario. The Ministry of Education and the University of Western Ontario wish to acknowledge the contributions of the following:

Writer:
Paul Park, Professor, Faculty of Education, the University of Western Ontario

Advisory Committee:
Kathy Berry, Teacher, London Board of Education
Ken Couchman, Superintendent of Education, Bruce-Grey County Roman Catholic Separate School Board
Jim McCallum, Science and Outdoor Education Resource Teacher, Middlesex County Board of Education
Suzanne Mercier, Teacher, École Alexandra, London Board of Education
Francine Morissette, Education Officer, Elementary Education Branch, Ministry of Education
Lise Savard, Professor, Faculty of Education, University of Ottawa
Susan Wallace, Environmental Studies Consultant, Peel Board of Education

Consultants to the Writer:
Barbara Park, Professor, Faculty of Education, the University of Western Ontario
John Smallbridge, Professor, Faculty of Education, the University of Western Ontario
R. H. Stinson, Head, Ontario Institute for Studies in Education, Western Ontario Centre
Del Wolsey, Consultant, London Board of Education

Co-ordinator:
A. H. Stahlke, Education Officer, Elementary Education Branch, Ministry of Education

Photographer:
John O'Sullivan, London, Ontario

(For list of validators, see p. 43.)

Contents

Introduction	4
Goals and Aims of Primary-Junior Science	6
Creating an Effective Classroom Environment	7
The Importance of Motivation	7
The Physical Environment	8
A Checklist of Considerations	8
Living Materials	9
The Learning Process	10
Exposure to New Learning Experiences	10
Processing New Learning Experiences	11
Consolidating New Learning Experiences Through Communication	12
Attitude Objectives	13
Knowledge Objectives	13
Skill Objectives	19
Observation Skills Sequence	21
Classification Skills Sequence	21
Seriation Skills Sequence	22
Communication Skills Sequence	22
Problem-solving in Science	24
Planning a Unit of Study	27
I. Growth in Animals - Primary Division	27
II. Batteries and Bulbs - Junior Division	30
III. A Problem-solving Approach to "Batteries and Bulbs"	36
Keeping Parents Informed	39
Resources	40

Introduction

Children are born into and grow up in an environment that is influenced greatly by science. They are naturally interested in all that goes on around them, and this natural interest and curiosity should be satisfied. The greatest value of science teaching in the early years is that it encourages children to discover - through direct experience, observation, questions, discussion, and simple experiments - the answers to some of the many exciting phenomena they continually encounter. More important than the knowledge children gain, at the Primary and Junior levels, are the methods by which they acquire it and the development and cultivation of the skills and attitudes of an enquiring mind.

Because of the way children see the world and the way in which they learn, the knowledge they acquire through science is inseparable from other areas of the curriculum. The attitudes, skills, and knowledge gained through the science program enhance many areas of learning. For example, the attitudes children develop towards life influence their views of the world and its people and help them define personal values. Similarly, the knowledge and skills they acquire through the study of science increase their expressive capabilities in language and the creative arts. In turn, the skills acquired in mathematics are basic to the measurement and observation necessary to science.

Moreover, the communication skills practised in all areas of the curriculum are essential for enabling children to represent and interpret the knowledge and experiences they acquire through their science study.

This document summarizes some of the current knowledge about science education in the early years and provides teachers with ideas, examples, and suggestions for classroom activities, for classroom discussion, and for reflection on current curriculum practice and teaching methodologies. It is suggested that teachers read the entire document before planning and implementing a classroom science program. They should discuss among themselves the nature of science teaching and programming for young children and should review the teaching strategies and learning styles discussed here, altering them if necessary.

Teachers should also have regular opportunities to discuss their implementation plans at the school level. At this time they can determine whether new or revised curriculum materials and learning activities are needed. Principals are encouraged to actively plan, establish, and monitor the implementation of science programs.

Many support services are available to teaching staff. These include:

- Science Teachers' Association of Ontario (STAO)
- faculties of education
- educational publishers
- Ontario Ministry of Education
- colleagues from other schools
- the Ontario Institute for Studies in Education and its regional field centres
- Ontario Teachers' Federation and its affiliates
- Council of Outdoor Education of Ontario

Goals and Aims of Primary-Junior Science

Science shares with other curricular areas of the Primary and Junior Divisions the general educational goals outlined in *The Formative Years:*

> On behalf of the educational community and other citizens, the Government pledges to support an education that develops basic skills, knowledge, and attitudes, that endeavours to provide a fuller life during a child's years in the Primary and Junior Divisions, and that endeavours to nurture every child's growth so that each may be able to continue his or her education with satisfaction and may share in the life of the community with competence, integrity, and joy.
>
> It follows that the curriculum will provide opportunities for each child (to the limit of his or her potential):
>
> - to acquire the basic skills fundamental to his or her continuing education;
> - to develop and maintain confidence and a sense of self-worth;
> - to gain the knowledge and acquire the attitudes that he or she needs for active participation in Canadian society;
> - to develop the moral and aesthetic sensitivity necessary for a complete and responsible life.[1]

The following specific goals are derived from these general goals. The science program in the Primary and Junior Divisions will provide opportunities for each child to:

- acquire the basic skills of observing, organizing, classifying, seriating, measuring, communicating, inferring, predicting, interpreting, hypothesizing, and controlling variables;
- develop psychomotor skills through regular physical involvement in his/her learning environment;
- experience joy and satisfaction from his/her daily study of the environment;
- acquire knowledge of the basic characteristics, structures, and forms of matter, life, energy, space, and time that are readily observable in his/her environment;
- acquire an understanding of the patterns and relationships among matter, life, energy, space, and time that are readily observable in his/her environment;
- develop attitudes of sensitivity, accuracy, objectivity, open-mindedness, honesty, and curiosity and compassion towards the environment;
- appreciate that the actions of individuals affect one's physical and social environments.

1. Ontario Ministry of Education, *The Formative Years* (Toronto: Ministry of Education, Ontario, 1975), p. 4.

In the Primary and Junior Divisions, science is part of environmental studies. The science program also shares the concerns of other areas of the curriculum, such as language arts, the arts, and mathematics. Science should acquaint children with their social and scientific environments and should help them to acquire the information and skills they will need to build a foundation for informed and rational attitudes and decisions, to use the enthusiasm generated by active investigation, and to acquire a reasoned knowledge of and pride in Canada.

As outlined in *The Formative Years*, the main aim of the science program in the Primary and Junior Divisions is to provide each child with opportunities to "understand the environment both in terms of the nature of its parts and of the patterns that characterize it as a whole". In order to accomplish this aim, children will be given opportunities to:

- develop an awareness of the natural environment and of how it affects and in turn is affected by human activities, past and present;
- develop an initial understanding of the relationships among natural things (e.g., the relationship between weather and erosion), among natural and manufactured things (e.g., between machinery and air pollution), and between people and things (e.g., between the quality of life and the automobile);
- perceive the development of patterns and relationships over time, such as the structure-function patterns of living things, the interdependence of living things, and the relation of the form and structure of materials to properties and function;
- develop concepts basic to science, such as matter, mass, force, energy, time, temperature, change, interdependence, growth, and development.[2]

Creating an Effective Classroom Environment

The Importance of Motivation

The way children feel about themselves has a significant influence on their academic performance. Extrinsic and intrinsic motivation both play an important part in developing and maintaining students' confidence and sense of self-worth. Extrinsic motivation involves such external rewards as good grades, praise from both teachers and peers, and additional privileges from parents. Intrinsic motivation involves such internal rewards as increased self-esteem and personal satisfaction. Students who have both kinds of motivation are more likely to succeed in school.

Teachers should seek to strengthen their students' motivation and positive attitudes towards science by demonstrating:

Warmth and caring. Students prefer teachers who make them feel good about themselves.

Empathy. Students respond best to teachers who demonstrate, through supportive interaction and communication, their respect for the young people with whom they work.

Interest. Students develop motivation when they observe a teacher who demonstrates a strong interest in science and a genuine desire to participate in their classroom experimentation and discovery.

2. *The Formative Years*, p. 22.

The Physical Environment

Children gain understanding most effectively through working with real materials and through studying concrete situations both inside the classroom and in the local environment. Thus, it is essential that the classroom have abundant concrete materials that can furnish opportunities for first-hand experiences. Science education in the Primary and Junior Divisions should focus on stimulating an interest in science exploration and an appreciation for science.

Very young children are at an early exploratory stage. Some may sustain an interest for a prolonged period, but the majority are unlikely to do so. Thus, a wide range of materials and opportunities for broad experiences and for allowing children to explore various problems is essential for science programs in the Primary and Junior Divisions. These materials and opportunities for experiences must be carefully chosen and should match each child's ability and stage of development. The teacher and children should also be constantly involved in discussions that enable children to solve the problems raised by the classroom or outdoor environment.

A Checklist of Considerations

The following checklist includes some of the things teachers can do to make the classroom environment conducive to learning:

- Curriculum materials (reference books, audio-visual materials, etc.) should be current, clear, and relevant to the children's needs, interests, and abilities.
- New or alternative teaching strategies should be considered for developing a strong foundation of basic skills during the child's formative years.
- The program, if it is to be stimulating and productive, should involve students in exploring knowledge, formulating and testing ideas, and interacting with their fellows.
- Teachers should keep a record of the skills outlined in the next section of this document to ensure they are actually developed in the science program.
- Children should record their activities and observations in a variety of ways, organize raw data in a variety of ways, collect material from their environment for use in the classroom, develop arts and communication skills through science activities, use measurement instruments and techniques for collecting and organizing data, and use a variety of media (oral, written, visual) to record their observations of, experiences with, and reactions to their environment.

- The classroom should be rich with resources that stimulate learning.
- Children should be given opportunities to conduct first-hand investigation.
- The outside environment should be used as a vehicle for helping students acquire special knowledge and skills.
- Children should be encouraged to generate and discuss questions about their environment.

Living Materials

The work in the science program should lead students to a greater understanding of the impact human activity has on the environment and to a greater appreciation of the problems of conservation. Although the children's study can be enriched through books, films, slides, or videotapes, the emphasis should be on the first-hand observation of living things. Much of the work done with animals and plants in schools will involve short-term observation (e.g., of movement, feeding, prenatal care, growth rates). Some long-term observations (e.g., of the relationships between land and the animals that live in it or on it) may also take place.

When these kinds of "experiments" involve living things, it is important not to cause them pain, suffering, or stress. Animals require sensitivity as well as careful tending. Although invertebrate animals, for example, snails or insects, do not show the same level of pain as do larger vertebrates, this does not mean they should be treated with any less care or respect. Care should also be taken that plants are not neglected and allowed to shrivel or become pot-bound.

Before deciding to keep living things in the classroom, teachers should ask themselves these questions:

- Have I a good and justifiable reason for keeping animals and/or plants in the classroom?
- Have I the necessary facilities? Are they safe? Do they avoid causing the animals stress?
- Am I prepared to spend the time, trouble, and money to ensure that the animals or plants are provided for?

If the answers to these questions are positive, then the following questions should be considered:

- What are the ideal conditions for the organism? Can they be satisfied in this school?
- What food or nutrient is needed? How often? Is it expensive?
- Who will be responsible for the organism throughout the day?
- Who will be responsible for it on weekends or during holidays?
- Are there likely to be offspring, and, if so, what will be done with them?
- Are there matters of hygiene, infectious diseases, allergies, bites, and smell to be discussed with the children? What action is required?

- Do the educational advantages outweigh the problems and difficulties?

The following advice will help teachers decide what kind of living things might be brought into the classroom:

- Such animals as hamsters, gerbils, and guinea pigs are very useful but should be purchased from accredited dealers who can supply disease-free stock.
- Such invertebrates as snails, spiders, caterpillars, or woodlice are probably the best organisms to keep because:
  a) they are easily obtainable from the wild;
  b) they do not transmit disease;
  c) they can be returned to the wild;
  d) they require less space and specialized equipment than do vertebrates.
- Wild vertebrates should not be trapped and brought indoors.
- Micro-organisms should never be cultured on agar or gelatin plates. Yeast is probably the only micro-organism that should be used in the classroom.
- Children should be taught never to put any plant material into their mouths. Many plants have poisonous or irritating parts; some fungi are very dangerous.
- Washing hands before as well as after handling animals and plants should be normal classroom procedure.
- Monkeys, wild mammals, or birds such as budgerigars and parrots should *never* be kept in the classroom, because they can transfer very dangerous diseases.
- Terrapins and tortoises may carry salmonella. For this reason, children should wash their hands carefully after handling them and might also use polythene gloves, which are cheap and disposable. (This also applies to cage-cleaning procedures.)
- Keep handy the address of a nearby veterinary surgeon or a local branch of an animal welfare agency. Either of these authorities can provide all necessary advice.
- Further information is available in the Ontario Animals for Research Act or from the Ontario Ministry of Agriculture and Food, 801 Bay Street, Toronto, Ontario M7A 2B2.

The Learning Process

Every learning experience incorporates the acquisition of knowledge with the development of skills and attitudes. Children must process each new learning experience so that it becomes part of the understanding they already have. The first step in this process is exposure to new learning, often through observation. This is followed by assimilation of the new learning; finally, the new learning is consolidated, often by being communicated to others.

Exposure to New Learning Experiences
New learning experiences initially involve children in an interaction with their environment through the senses. In the study of science, children observe real things and events by using sight, hearing, touch, smell, and taste purposefully, and by extending and sharpening their senses by means of instruments and measuring devices. Observation and participation in activities should stimulate their curiosity and lead them to further investigation.

The depth of observation expected of each child will vary according to age and ability. Thus, more detailed observation would be expected from ten-year-olds than from six- or seven-year-olds. For example, during a class outing a seven-year-old might notice that an insect has six legs and four wings; a ten-year-old might also note that the insect's legs are jointed and the wings are veined.

When observing, the child should be looking for patterns and relationships. Repeated observations and discussions of these patterns and relationships should then give rise to generalizations. For example, a child might generalize that all trees have trunks, branches, and leaves. At a higher level, the child might discern patterns of life cycles, such as that all birds lay eggs but most mammals bear their young alive.

Having opportunities for observation or obtaining information from a teacher or a book is just the beginning of learning, however. Touching, tasting, smelling, listening to sounds and talk, or seeing real things or reading about them don't take a child very far; such experiences are merely primers.

Processing New Learning Experiences

Once children have obtained information through observation and experience, they must process it, using thinking skills (for example, organizing, classifying, seriating, measuring, inferring, predicting, interpreting, hypothesizing, controlling variables), in order to assimilate it into their ways of thinking about the world.

New information that doesn't fit the mental categories children have constructed requires them to make accommodations. Accommodating new information by modifying their mental categories allows children to extend their understanding. They may reorganize existing structures or construct new ones. Such accommodation can be reinforced by giving children examples of a concept in different contexts and forms. Thus, the concept is not only fixed in the children's minds but also allows for further assimilation. The ability to accommodate new information in this way is at the heart of problem-solving.

It is best to avoid testing what children have gleaned from their observations before they have had a chance to process the new information by organizing it and presenting it to others through physical actions, models, pictures, maps, diagrams, graphs, and especially by putting it into their own words, either orally or in writing. By explaining to others what they have learned, children are able to clarify new learning both for themselves and for their audience.

Given this view of learning, personal, exploratory, working representations should be encouraged. For example, if a child attempts unsuccessfully to model or to tell or write about a turtle, he/she should be encouraged to look at the turtle again. In this way, first attempts to represent concepts, ideas, or things may be discarded or revised repeatedly until the child reaches a degree of satisfaction.

The more diversified and frequent the exploratory representations, the greater will be the learning, not only of the content but also of the thinking and language skills involved.

Consolidating New Learning Experiences Through Communication

Children should be given opportunities to interact with peers, parents, and teachers to ensure that they understand and consider different viewpoints. Such interaction will stimulate them to analyse and assess new information in the light of their own and others' observations. These experiences can be further enhanced if children are taught some specific questioning skills.

Talking with others is only one way in which children can communicate and clarify what they have learned. They should also be encouraged to relate their attempts at accommodating their new learning through a wide range of media (for example, through written work, models, pictures, diagrams, songs, and mime). As well, children should be given additional opportunities to broaden and fit their new learning into existing mental structures by experiencing the new concept(s) in stories, poems, filmstrips, books, pictures, films, songs, and real-life experiences. In this way, children begin to feel comfortable and confident about their new learning. This process is evident in the following poem, in which a Grade 4 student has consolidated new learning:

I used to be a worm
But now I am a beetle.
Don't you think I'm clever
To be a worm that turns
Into a beetle?

I used to be a tadpole
But now I am a frog
Don't you think I'm clever
To be a tadpole that rolls
Into a frog?

After watching a film on animals that change in structure and form as they grow, this child could possibly add more verses to the poem.

Attitude Objectives

Science skills and methods are of little value if students are not inclined to use them appropriately. Teachers should encourage their students to develop these traits:

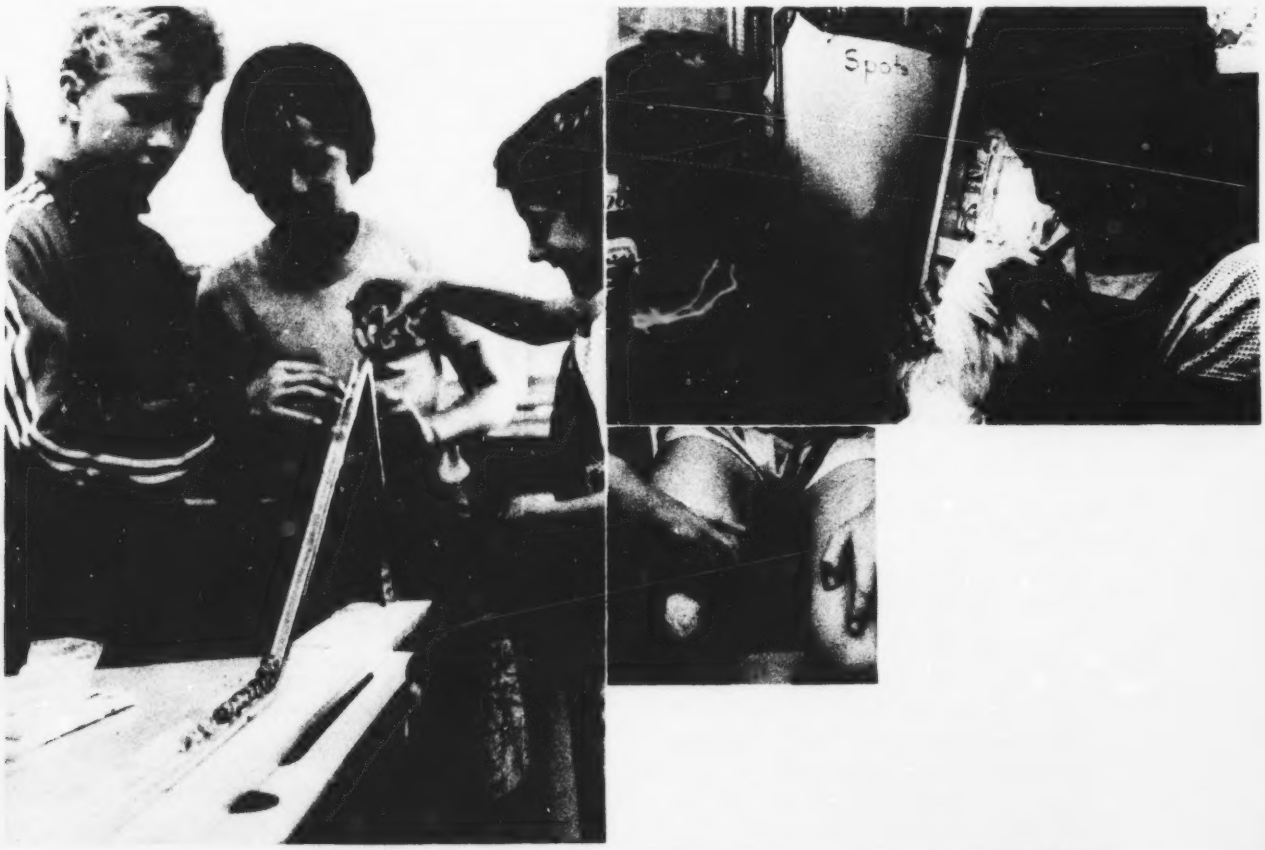
- accuracy in searching for evidence
- objectivity in challenging ideas, hypotheses, and conclusions
- open-mindedness in listening to and considering the ideas of others
- curiosity in asking questions
- persistence in a task
- sensitivity and compassion in dealing with others and with the environment

The classroom practices of teachers themselves can provide a model of these attitudes. With this model, and through a conscious effort as they work together, students will develop the attitudes they need to achieve success in their study of science.

Knowledge Objectives

The science curriculum in the Primary and Junior Divisions should progressively develop in children the knowledge they need to inquire effectively and to make informed and rational decisions. Thus, each child should be given opportunities to learn the basic characteristics, structures, and forms of matter, life, energy, space, and time that are readily observable in his/her world and to identify patterns and make generalizations.

In the development of the science program, specific instructional objectives must be selected carefully, according to the learning capacities of Primary-Junior children. Although it is difficult to identify a natural order in the body of scientific knowledge, broad classifications of knowledge and levels of difficulty are useful in deciding the relative position of each item.[3] For example, it is possible to decide whether a particular item of content involves simply the recall of a fact or whether it involves the understanding of complicated relationships. In other words, it is possible to determine the kind and level of thinking that children require in order to master a particular item of content.



3. See, for example, Benjamin Bloom, ed., *A Taxonomy of Educational Objectives: The Classification of Educational*

To help classroom teachers and resource staff choose suitable program content, this section lists the content appropriate for children in the Primary and Junior Divisions. This content is sequenced according to child development from Kindergarten to Grade 6 and is organized according to the components of the environment: energy, matter, time, life, and space. The items selected reflect the view that Primary and Junior children form concepts and make generalizations through repeated exposure to real things and events in their environment. The knowledge sequences presented below are not intended to be exhaustive or restrictive. Instead, they are furnished as a first step to help teachers and curriculum writing teams select appropriate science content.

Students in the Junior Division are capable of logical thought about the relationships among concepts, provided that the relationships are established through direct experience. Some of these students, particularly those in Grade 6, may also be capable of abstract thought, through which new concepts and relationships are formed, and may be able to deal with content that is not immediately observable in their environment. Through such teaching strategies as the Socratic method, reasoning by analogy, and abstraction from models, these children may, from time to time, be presented with concepts that go well beyond the material suggested here. *It should be remembered, however, that even for children capable of abstract thought, concrete experiences are the best foundation for developing in-depth understanding, skills, and attitudes.*

In addition to the topics listed on the following pages, a number of broad integrated concepts, such as change, variation, and the role of technology, can be developed for each environment component. There are also many topics that students are naturally curious about, for example, space travel, astronomy, oceanography, flight and kites, science and magic, toys, computers, Canadian scientists, robots, and medical discoveries. Although these topics do not fit neatly into any of the environment components of energy, matter, time, life, or space, children should be given opportunities to become more familiar with them, because these topics often involve technological advances and their applications in everyday life.

Kindergarten
Children will be given opportunities to:

Energy
- recognize the colours of the rainbow;
- observe motion (still/not still, push/pull);
- learn directions (up, down, near, far);
- observe differences in sound (pitch, loudness, duration);
- make comparisons of temperature (hot, cold, warm, cool);
- observe changes in things around them;

Matter
- compare the masses of two objects (lighter or heavier);
- recognize and name a wide variety of objects in the environment;
- recognize and name a wide variety of common substances in the environment;

Time
- use meaningful vocabulary to relate the sequence of events (morning, afternoon, day, night, before, during, after) and seasons;
- experience long and short intervals of time;

Life
- recognize and name a wide variety of common living things in their environment;

Space
- identify, describe, and classify objects in the environment by such attributes as shape, size, thickness, colour, and texture;
- build models of objects using sand, blocks, and so on;
- compare amounts of sand, water, etc., contained in two different containers;
- compare two objects (length, mass, colour, etc.);
- describe and classify surfaces of various objects;
- describe, identify, and classify three-dimensional figures resembling balls, cones, boxes, and cans.

Grade 1
Children will be given opportunities to:

Energy
- describe and classify colours;
- observe different aspects of motion (acceleration, deceleration, steady speed);
- describe differences in sound (pitch, loudness, duration);
- associate different temperatures (in degrees Celsius) with feelings (hotness, coldness);

Matter
- compare masses of objects by experimenting with balances;
- develop appropriate vocabulary for describing the absorbency of matter;
- learn that some objects can be seen through and some cannot;
- observe the pourability of objects and substances;

Time
- place events of the day, week, or year in sequence;
- experience short time intervals and the length of the day;
- learn to tell time to the nearest hour;

Life
- explore the similarities and differences among living things (coverings, body parts, forms, structures, mobility, etc.);
- describe the seasonal changes in the natural environment;

Space
- develop and use vocabulary related to length, area, and volume;
- identify the attributes of three-dimensional shapes;
- identify squares, rectangles, triangles, and circles;
- develop vocabulary related to the movement of shapes (up, down, over, sliding).

Grade 2
Children will be given opportunities to:

Energy
- seriate and mix colours;
- observe objects in motion;
- experience measurable speed;
- experience changes in direction of motion;
- exert force to move heavy and light objects;
- classify and seriate sound according to pitch, loudness, and duration;

Matter
- order three objects by mass;
- describe objects or substances by using appropriate vocabulary based on how well they can be seen through;
- bend, break, and stretch materials and describe what happens;
- develop appropriate vocabulary to describe the taste, odour, and texture of a wide variety of materials and objects;
- learn that objects have a definite shape, that substances have no definite shape, and that objects are made of substances;
- recognize that the definite shape of objects can be damaged or changed by bending, stretching, etc.;
- observe that some objects have parts and that others do not;
- observe that some substances can be mixed together;
- describe objects or substances in terms relating to their physical properties;
- classify, seriate, and investigate objects and substances on the basis of their observable properties;

Time
- use devices to establish arbitrary units of time;
- tell time to the nearest quarter and half hour;
- use the following relationships: days to weeks, weeks to months, months to years;
- distinguish between regular and irregular events (the seasons, the death of a guinea pig);

Life
- distinguish between a plant and an animal;
- learn that all living things have coverings that protect and contain their bodies;
- learn that animals use shelters for protection or warmth;

- learn that animals move in different ways in order to satisfy basic needs;
- learn that some animals recognize parental care;
- learn that plants cannot move about to obtain food, water, and warmth;
- learn that all living things need warmth, food, water, and air to stay alive;
- learn the ways in which animals protect themselves from predators;
- learn that all living things have body structures to help satisfy their needs;
- learn that some animals require rest and physical activity in order to thrive;

Space
- classify three-dimensional shapes by their attributes;
- construct three- and two-dimensional models;
- learn about the relationship between three- and two-dimensional shapes;
- continue to develop the use of vocabulary related to length, area, mass, and volume;
- use arbitrary units and the metre to estimate and measure length.

Note: The learning opportunities for matter and life are common to Grades 2 and 3.

Grade 3
Children will be given opportunities to:

Energy
- seriate and mix colours;
- observe objects in motion;
- experience measurable speed;
- experience changes in direction of motion;
- observe the force of things (magnets, springs, moving water, animal muscles) that are used to move objects;
- observe the loudness, pitch, and duration of sound;
- test and use simple machines to make work easier;
- measure temperature to the nearest degree Celsius;

Matter
- order three objects by mass;
- describe objects or substances by using appropriate vocabulary based on how well they can be seen through;
- bend, break, and stretch materials and describe what happens;
- develop appropriate vocabulary to describe the taste, odour, and texture of a wide variety of materials and objects;
- learn that objects have a definite shape, that substances have no definite shape, and that objects are made of substances;
- recognize that the definite shape of objects can be damaged or changed by bending, stretching, etc.;
- observe that some objects have parts and that others do not;
- observe that some substances can be mixed together;
- describe objects or substances in terms relating to their physical properties;
- classify, seriate, and investigate objects and substances on the basis of their observable properties;

Time
- place events of the day, week, month, or year in sequence;
- use time lines;
- learn to tell time in five-minute intervals;
- learn to use conventional measures of time (day, week, month, year, second, minute, hour);

Life
- distinguish between a plant and an animal;
- learn that all living things have coverings that protect and contain their bodies;
- learn that animals use shelters for protection or warmth;
- learn that animals move in different ways in order to satisfy basic needs;
- learn that some animals recognize parental care;
- learn that plants cannot move about to obtain food, water, and warmth;
- learn that all living things need warmth, food, water, and air to stay alive;
- learn the ways in which animals protect themselves from predators;
- learn that all living things have body structures that help satisfy their needs;
- learn that some animals require rest and physical activity in order to thrive;

Space
- identify and classify polygons;
- investigate symmetry;
- learn about ideas of scale;
- estimate and measure length, area, mass, and volume using arbitrary units;
- estimate and measure using the standard units of metre, centimetre, kilogram, and litre.

Note: The learning opportunities for matter and life are common to Grades 2 and 3.

Grade 4
Children will be given opportunities to:

Energy
- describe *work* as a push or pull on an object that causes motion;
- describe *energy* as the ability (capacity) to do work;
- manipulate materials in order to observe the behaviour of static (electric) charges;
- perform simple tests with batteries, bulbs, and battery-operated objects;
- learn that electricity flows through a circuit;
- learn that sound is produced by vibrations;
- perform simple tests that demonstrate that sounds can be changed in pitch and loudness;
- learn the sources and uses of energy at home and in school;

Matter
- determine similarities and differences among sets of materials (powders, rocks, shells);
- describe the properties of similar sets of materials;
- group sets of objects on the basis of observed physical properties;
- observe the chemical properties of some forms of matter (baking soda and vinegar, growth of crystals);
- investigate and observe the physical properties of matter (nail, light bulb, glass, flour);

Time
- tell time in one-minute intervals;
- recognize the relationships among seconds, minutes, hours, days, months, and years;
- recognize cyclical occurrences (phases of the moon, seasons of the year);
- record changes in events or objects, using time lines;

Life
- learn the differences between a plant and an animal;
- learn that all living things reproduce, grow, and breathe;
- learn the conditions necessary for plant growth;
- compare a variety of animals to determine similarities and differences;
- learn about the life cycles of some common plants in their immediate environment;
- observe the behaviours of common insects (methods of breathing, eating, reproduction, locomotion, socializing, searching for food);

Space
- estimate and measure length to the nearest centimetre;
- estimate and measure capacity to the nearest litre;
- estimate and measure mass to the nearest kilogram;
- classify common three-dimensional shapes according to their number of faces, edges, and/or vertices and relate examples of them to the environment;
- recognize congruent two- and three-dimensional shapes;
- recognize symmetrical two- and three-dimensional shapes.

Grade 5
Children will be given opportunities to:

Energy
- learn that gravity is an invisible force attracting objects to the earth;
- perform simple tests to discover the factors affecting the swing of a pendulum;
- learn that for every action there is an equal and opposite reaction;
- find out what materials magnets can attract;
- observe the patterns of iron filings around a variety of magnetic shapes;
- test a variety of magnets to determine their strength (attraction and repulsion);
- learn that a free-swinging magnet can be used to find magnetic north;
- observe that light travels in a straight line;
- predict the path of a ray of light when it is reflected from a mirror;
- learn that light can be broken into primary colours when it is passed through a prism;
- learn that light can pass through some materials;
- learn about some major forms of energy (solar, mechanical, animal, fossil-fuel);
- test and use simple machines (first-, second-, and third-class levers);
- learn about sources and uses of energy for homes, farms, transportation, humans;

Matter
- describe *matter* as anything that has mass and occupies space;
- observe a variety of objects and substances and group them according to observed properties;
- describe solids, liquids, and gases;
- classify matter as solids, liquids, or gases;
- observe how a few easily changed substances (water, clay, flour) change from one state of matter to another;
- observe the natural change of a variety of substances and objects over a period of time and predict their future change;
- perform tests to speed up or slow down the change of some substances or objects;

Time
- estimate and measure time to the nearest second;
- use twenty-four-hour-clock equivalents to the nearest minute;
- estimate and measure distances and the time that objects take to travel those distances (rate);
- estimate and measure the speed and direction of the wind;
- estimate and measure absorption and evaporation rates;
- estimate and measure the accumulation of melting snow, ice, or rain over a period of time;

Life
- observe that all the leaves on a single plant are not identical;
- observe the wide variation within the human species (colour of eyes, hair, skin, fingerprints, freckles);
- observe and record differences within plant and animal species;
- learn a simple system for classifying plants and animals;
- learn the ways in which plants and animals may interrelate within a community (animals eat plants, disperse seeds, and eat other animals; plants provide protection for animals);
- recognize that nearly all living things are dependent on other living things for survival;
- learn the roles played by producers and consumers in a natural community;

Space
- estimate and measure length to the nearest millimetre;
- estimate and measure volume to the nearest cubic centimetre;
- estimate and measure capacity to the nearest millilitre;
- estimate and measure mass to the nearest gram.

Grade 6
Children will be given opportunities to:

Energy
- learn that a moving object has the ability to do work;
- learn that the greater the mass of an object, the greater the force required to change its motion;
- learn that heat is a by-product of friction;
- learn that electrical energy can be changed into other forms of energy;
- construct and use electrical circuits;
- learn about short circuits;
- learn about magnets;
- construct and use an electromagnet;
- learn that simple machines such as levers and pulleys are devices that change the strength and direction of forces;
- learn that complex machines are made of two or more simple machines;
- observe the transfer of energy from one form to another;
- learn about renewable and non-renewable sources of energy;

Matter
- learn that a solution is a mixture of two or more substances, one of which is usually a liquid;
- learn that some solutions may be separated into their component parts;
- observe the growth of crystals in solutions;
- observe a variety of examples of natural crystal formation;
- learn the characteristics of common soil types (clay, loam, sand);
- learn that humus is organic material present in soil;
- perform simple tests to determine the ability of different soils to absorb water, retain moisture, and grow certain types of plants;

Time
- recognize that parts of seconds of time are expressed in decimal form;
- use twenty-four-hour-clock equivalents to the nearest second;
- estimate and measure the time required to boil or freeze liquids;

Life
- develop examples of simple food chains in different natural communities;
- recognize that change is an ongoing process within a natural community;
- learn the names of the common plants and animals in the immediate environment;
- learn that plants can reproduce in a variety of ways;
- learn that plants and animals are made up of cells;
- observe the behaviour of common micro-organisms;

Space
- estimate and measure length to the nearest millimetre;
- estimate and measure volume to the nearest cubic centimetre;
- estimate and measure capacity to the nearest millilitre;
- estimate and measure mass to the nearest gram.

Skill Objectives

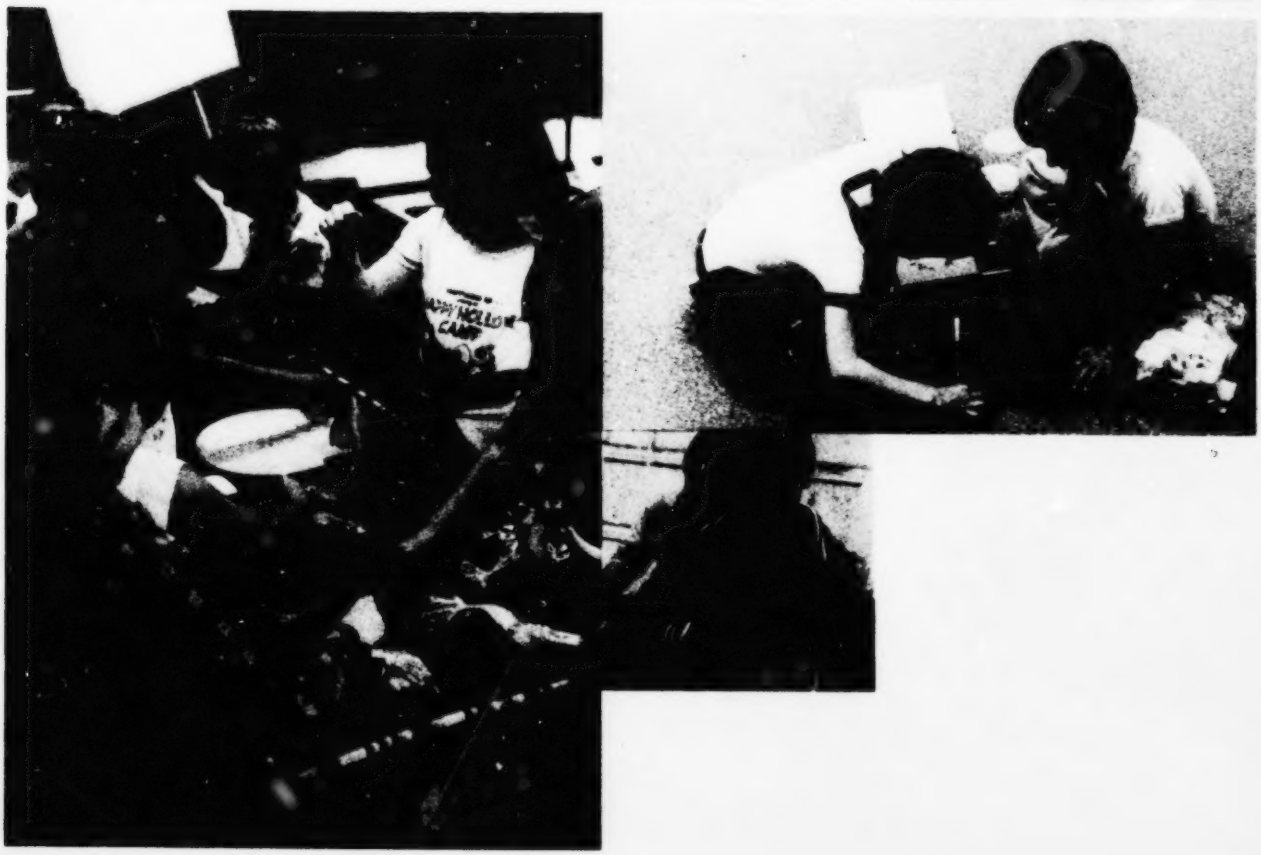
As already suggested in this document (see the section entitled "The Learning Process"), experiences in science begin with *observation*. Conducting observations involves using skills that rely on the senses to obtain data or information. At a basic level this information relates to the attributes of things (bright, dull, colour, high, low, long, short, small, large, cold, warm, hot, wet, dry, smooth, rough, sticky, sweet, spicy, loud, quiet, sour, salty). Children's observation skills can be progressively developed from Kindergarten through Grade 6.

The processing of collected data involves other *thinking* skills. To process information they have collected into personal knowledge, children also use the following thinking skills:

- *Classifying.* Children sort objects, ideas, or events into groups according to some pattern, for example, according to similarities or differences.
- *Seriating.* Children place objects, events, or conditions in some kind of order (shortest to longest, lightest to heaviest).
- *Measuring.* Children describe and communicate their descriptions (both estimation and verification) by using arbitrary units (hand spans, arm lengths, strides) and standard units (distance, time, length, mass, speed, temperature, area, volume).
- *Inferring.* Children attempt to guess the reasons for their observations.
- *Predicting.* Children suggest possible outcomes, predict results, or make educated guesses based on ordered data and then verify their predictions through first-hand experiences or simple experiments.
- *Interpreting.* Children express ideas or meaning (generalize) from the information or data they have gathered.
- *Hypothesizing.* Children explore their observations and advance data to support their thinking.
- *Controlling variables.* Children identify factors affecting results.

Children consolidate their learning through *communication*. In communicating, they develop a whole new range of skills, which can be practised in many ways throughout the Primary and Junior years. The following are a few examples:

- oral exchanges (discussions, interviews)
- visual presentations (graphs, pictures, charts, models, diagrams, maps) using a variety of media (paper, paint, clay, string)
- simple written reports involving the acquisition and use of new vocabulary
- movement (pantomime)



The thinking skills of observing, classifying, seriating, measuring, inferring, predicting, and communicating are gradually developed throughout the Primary and Junior Divisions. Interpreting, hypothesizing, and controlling variables are more complex skills that are more effectively learned by children in the late concrete and the formal operational stages of cognitive development.

At the same time as they develop the above skills, students should develop *psychomotor* skills. These skills include the development of mind-body skills ranging from the co-ordination necessary for handling simple tools to the complex communication skills of dance and pantomime. Psychomotor skills are developed by involving children in such learning activities as:

- using hand tools to build a simple apparatus;
- measuring using hand spans, string, metre sticks, containers;
- using apparatus;
- acting out ideas or statements (for example, through pantomime).

In order to acquire an aptitude for varied physical activities, each child must have daily opportunities to work with concrete materials. In the study of science, pencils, paper, crayons, and books are not enough. Children must also be equipped with the materials necessary to see, feel, and measure.

Learning skills are essential to all areas of study; they certainly are not limited to science. For example, any of the skills discussed above may be developed in the context of language arts or mathematics programs. Occasionally, a skill may also be developed independently of the science content of the classroom program. For example, some teachers believe that a skill such as cross-classification may be taught effectively with simple materials such as attribute blocks. Other teachers find, however, that skills taught in isolation in this way are rarely transferred to new situations.

The following are examples of classroom activities that develop some of the skill areas listed above. They concern the skills applicable to students at the pre-operational and concrete operational stages of cognitive development.

Observation Skills Sequence
Through observation, children acquire data from the environment. It is the teacher's role to give children opportunities to observe and to use all of their senses to acquire information. Observation arouses children's curiosity, often because the information they receive does not fit their mental structures.

Pre-operational Stage of Development
- Through any one of the five senses a child can:
  a) tell one thing about an object or event ("It feels rough.");
  b) tell several things about an object or event ("It smells sweet and flowery.");
  c) locate an object or event, given a particular feature (an instrument that makes a tinkling sound);
  d) locate more than one object or event, given a particular feature (all the foods on the table that smell sweet).
- Using all the senses and appropriate aids, a child can tell many things about an object ("The apple tastes sweet. It has a shiny skin. It is red and round. It has a green stem. It smells fruity.").

Concrete Operational Stage of Development
- Using the appropriate senses, a child can observe how doing something to one part of a system affects the entire system ("The plants I watered got taller. The plants I didn't water are shrivelled up. There are no new leaves on them. I wonder if this plant will die if I never water it?").
- The child determines which observations could be relevant to a problem. For example, when asked "Are all apples red?", the child plans (a) to observe the colour of apples at the supermarket and (b) to talk to an apple grower.
- The child can extend his/her range of perception through simple material aids (measurement tools, for example, a thermometer or a trundle wheel, lenses of various kinds).

Classification Skills Sequence
Classifying is one of the most important thinking skills, because it enables a child to perceive an event in terms of the class of events to which it belongs rather than as an individual event. In planning activities to help children grasp this concept, teachers should always include opportunities for classifying information that children have collected from their observations.

Pre-operational Stage of Development
When asked to sort objects, the child:

- does not sort, but plays at a level that demonstrates that he/she is noticing likenesses and differences in materials. For example, if a truck that the child builds has round blocks for the wheels, he/she is demonstrating an understanding of the "roundness" of wheels;
- groups together only a few objects with common properties, showing that he/she responds to immediately apparent similarities and differences but with no overall guiding plan;
- can determine whether a particular object or event belongs in a group. For example, given a set of yellow triangles, the child knows whether a yellow square belongs with the triangles;
- can select from a collection *all* the objects or events that have the same attributes;
- can choose a criterion and divide a collection of objects into two or more separate groups and can then repeat this skill with the same objects but according to a different criterion. For example, given objects of varying shapes, the child might first divide them according to roundness (round/not round) and then according to size (large/small).

Concrete Operational Stage of Development
When asked to sort objects, the child:

- can divide objects into two or more separate classes based on two or more criteria. For example, given a collection of objects and asked to find all the rough, red ones, the child selects *all* the rough, red objects, leaving none out;
- recognizes that objects may belong to more than one group at the same time. For example, when given several red squares, the learner recognizes that the objects can be classed in the red group *and* in the square group;
- recognizes that objects may fit into the intersection of two overlapping groups. For example, when shown two groups of objects, such as red blocks and cubes, and five additional objects, the child can select the objects that belong in both classes;
- can construct and interpret an appropriate representation, such as a Venn diagram, a cross-classification table, or a tree diagram.

Seriation Skills Sequence
Seriation involves arranging objects, events, or conditions in an order based on some common attribute. Things are often neither black nor white, but run instead on a continuum from black to white. In such situations, then, the sensible way to organize elements is not to classify or group them but to seriate or order them.

Children at the pre-operational stage of development can make simple comparisons, but they cannot seriate. This is because seriation is an operation, and children can only operate on elements that they can conserve. Teachers may find it difficult to teach seriation, because all children do not learn to conserve all elements at the same time. For example, six-year-olds can conserve number but not length; seven-year-olds can conserve number, length, and often distance, but not volume or area. Thus, the teacher must examine an element carefully before asking a child to seriate it, since the operation may exceed the child's ability or stage of development.

Pre-operational Stage of Development
At this stage of development the child can:

- compare two elements (objects, events, conditions) and choose the one that exceeds the other in some dimension (which of two sticks is longer, or which activity of two, such as clapping hands or eating breakfast, takes more time);
- select from a set one element that exceeds another in some dimension (from a group of sticks, finding a stick that is longer than a given stick or determining which event comes earlier in the day - getting out of bed or going to school).

Concrete Operational Stage of Development
At this stage of development the child can:

- replace an element that has been removed from a series of three or more;
- arrange three or more elements into a series (ordering a set of sticks from longest to shortest, four pictures according to the time sequence in which they occur, or four temperatures, taken on different days, from hottest to coldest);
- seriate a group of elements along one dimension and then reseriate the same elements along another dimension (for example, first ordering a group of shapes according to their size and then according to their number of sides);
- construct a diagrammatic representation of a serial arrangement (a time line or A›B›C›D).

Communication Skills Sequence
The following lists of skills are essentially for non-verbal modes of representation, because a detailed outline of the skills involved in language acquisition is more appropriately dealt with in a language arts document. The skills presented here are especially useful in scientific inquiry and are often ignored or given second place to language skills. It is hoped that the following skills sequence will encourage teachers to seek in their programs a balance between non-verbal and verbal (both oral and written) forms of expression.

Pre-operational Stage of Development
Motor activity is enormously important for understanding spatial thinking. If they are to construct adequate mental representations, children should be given many opportunities to handle objects and trace outlines of objects with their fingers and hands. Showing and telling is not enough. Children must form their own mental constructs, based on their physical actions on objects, before they will be able to represent them. At this stage children can recognize and represent only those objects and events that they can actually reconstruct by modelling with their own actions.

The child can:

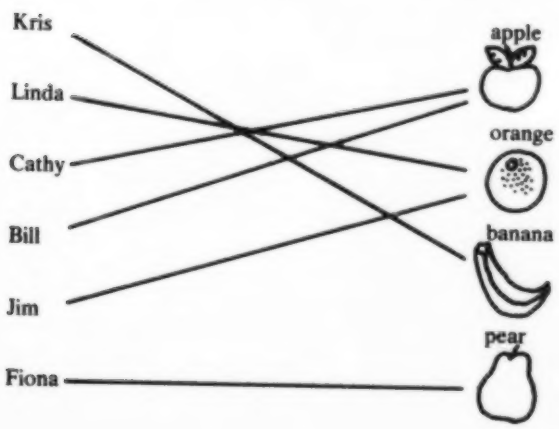
- symbolize through action something that is not present (through imitative performances such as role play);
- make representations of the objects in the world as he/she sees them (through picture-making the child records events and perceptions of the environment);
- manipulate concrete materials to illustrate the data that he/she gathers. The actual objects of investigation are used in building the representation (constructing models using blocks, boxes, toys, and other objects);

- build models to represent real situations. The child can use scrap pieces of wood, fabric, paper boxes, clay, and other materials to represent houses, streets, machines, or pets. Three-dimensional models can also be arranged out of models at the sand table. The scaling will not be precise; the rough proportioning usually reveals the children's perception of what is most important to them at the time. As they gain experience in making models and pictures, their products become complex. Not only do they attempt to enlarge the scope of their representations, but they also add more details, according to their perception of things, people, and events;
- use words, pictures, and physical objects to represent real things. The representations made are early stages of graphing, in which the units chosen bear a strong similarity to the real objects (boys are lined up beside girls to compare "how many"; the learner then draws pictures to represent girls and boys);
- make pictures of real situations, events, and perceptions, using a variety of materials (paint, crayons, small objects, fabric). The pictures should show relationships in size and number as well as orientation in space (up, down, near, far, left, right);
- construct a two-dimensional layout (road, house, tree, girl, store, car) based on a model provided and using materials supplied by the teacher. Although complete success in this activity requires an understanding of distance and length, all children should be given an opportunity to try it.

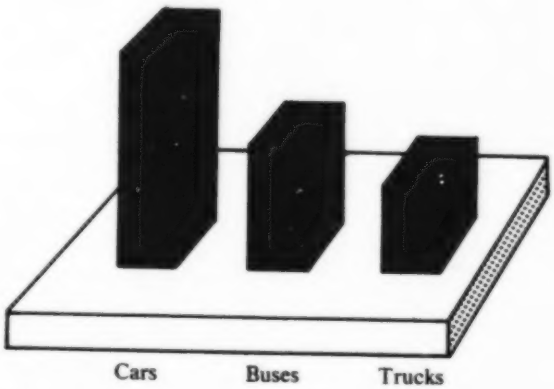
Concrete Operational Stage of Development

At this stage of development the child can:

- show relationships between sets of real things and events by mapping or graphing. This correspondence may be one-to-one or many-to-one. For example, in mapping children and their favourite fruits, the child makes vertical lists of names and fruits. Each name is then mapped to each child's favourite fruit.

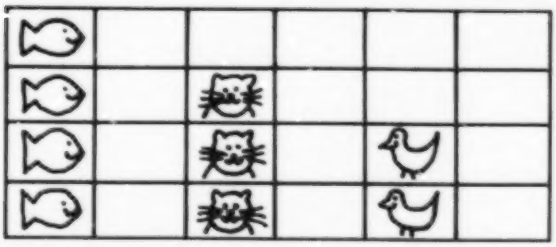


Throughout the Primary grades, children should graph at the one-to-one stage (one block represents one girl or one coat, a sticker represents one person or place or thing). The accompanying sample is a graph of a child's traffic count of cars, buses, and trucks over a short period of time. The data are displayed through the use of stacks of identical blocks. Colour coding can be used to distinguish the cars, buses, and trucks;



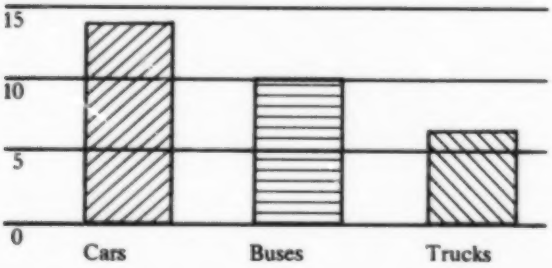
- build three-dimensional models representing real situations (individual or group models of playgrounds, places, neighbourhoods), by using miniature street lights, mail boxes, traffic signs, people, and animals. The positioning and proportions of these models will, of course, be approximate;
- build a three-dimensional setting which is proportionate to models of cars, ships, animals, etc., which are used in the setting. Repeated experiences of this kind not only increase children's skill in approximating and scaling, but also help them to see objects from a different point of view and give them more experience in estimating distance and orientation;
- make diagrams or sketches representing a two-dimensional layout in which a frame of reference (co-ordinate axes) locates the objects. At first the child is given a simple layout of objects (house, church, school, girl, stove, car) from which he/she draws a reproduction as seen from above at an angle of 45°. The piece of paper should be the same size as the model. The activity can then be repeated on paper that is smaller than the model. This second drawing will then involve a reduction in scale or ratio. The learner must use either the edges of the paper as a basis for establishing a frame of reference or co-ordinate axes to locate objects on the copy;

- construct graphs in which a dual-reference system (co-ordinates) is used to record and locate information. For example, if each child makes on identical sheets of paper a drawing of his/her favourite pet, the drawings can be displayed on a rectangular grid like the following:



Fish Cat Bird

By tallying, a traffic count over a longer period of time than the one outlined above can be made. The data can then be displayed in a bar graph (the bar can be a strip of paper or can be shaded);



- investigate the symmetry of two- and three-dimensional shapes. He/she can make ink-blot patterns by folding paper. One, two, or more colours of fingerpaint can be used. With experience the child will experiment with more complex examples of symmetry and will attempt to predict and then describe shapes and relationships;
- develop mapping skills by using a shadow box to investigate the length and direction of shadow images. The box is made from cardboard and has translucent windows of paper on the sides and top. An electric bulb or a flashlight is placed inside it. When an object is placed in the box, its shadow is projected, and the child attempts to interpret and draw it;
- use diagrams to classify objects and numbers by their attributes (including intersection of sets);
- find patterns based on operations when given input and output values;
- use the idea of horizontal and vertical as a constant reference system in space. An overhead projector can be used to allow children to examine enlargements and note correspondences. It is also useful for discussions of colour and composition.

Problem-solving in Science

The development of a child's ability to make informed and rational decisions is one of the aims outlined in *The Formative Years* for the Primary and Junior Divisions. For children, developing this ability involves:

- organizing personal questions and interests and participating in purposeful first-hand investigations;
- practising the scientific method, that is, learning to make careful and objective observations, to distinguish between observation and inference, and to make predictions and generalizations.

Although these skills are called upon in a number of subjects across the curriculum, science study provides many opportunities to develop and practise them.

It is important for children to learn how to solve problems, both individually and in groups. The most productive methods seem to have a common sequence of steps, that is, students are first introduced to activities that stimulate their curiosity and then they:

- identify a question or problem from these activities;
- suggest possible answers to the problem;
- make a plan to gather information about the problem;
- collect and organize the information;
- interpret the results;
- draw conclusions from the results;
- apply the conclusions;
- report on the entire problem-solving procedure.

The following case study illustrates this sequence of steps for problem-solving. A Junior Division class had been working on a unit in which the students were growing seeds, and the students had a number of questions about growth.

Identifying the problem. The students asked questions about the parts of a seed: Where did growth begin? Was there a growing point or embryo? What did the thick seed leaves or cotyledons do? Finally, the students decided to investigate the purpose of the cotyledons.

Suggesting possible answers. With the teacher's encouragement, the students began to suggest answers: the cotyledons might exist for protection or as a food supply for the growing embryo. The teacher asked them to explore these possibilities further. If the cotyledons provided food, would the embryo then be able to grow on its own? If they were not necessary as food and if the embryo were already protected, perhaps the cotyledons would not be needed at all. The children were then asked to find the answers to these questions about the role of the seed leaves. They decided to try to find out if the cotyledons provided food.

Making a plan for collecting information. The children agreed that they could obtain information about this problem by doing an experiment. They knew how to grow seeds on moist blotting paper in jars. They decided to work with several jars: one containing only the embryo; one containing a small portion of the seed leaf; one containing a whole cotyledon; and one containing both cotyledons. After further discussion with the teacher, they realized that they would have to keep each jar in about the same place so that the seeds would all have about the same amount of light and the same temperature. They also knew from their previous experiments that they were going to have to agree on ways of measuring growth.

Collecting and organizing the information. They divided into groups, and each group set up and carried out an experiment. They established a schedule for observations; they took measurements; they made notes about other developments they had not predicted. As they took down their observations, they found that they had to keep them in some systematic order, and so they used a rough chart.

Interpreting the results. After three weeks, enough growth had occurred so that comparisons could be made between the different jars. To do this, the students drew graphs from the measurements in their charts, showing how the length of the growing parts had changed. From the graphs the group could compare their results and could guess at what might happen if the experiment continued. It turned out that the embryo grew very little by itself; when attached only to a small part of the seed leaf, however, the embryo grew just as well as those with one or both seed leaves.

Drawing conclusions. Looking back at their original two possible answers, the students concluded that the cotyledon was needed for growth, but not much of it was needed during the early stages. This conclusion raised a number of other questions that they then wanted to investigate.

Applying the conclusions. It was not easy to generalize from the conclusions. There are so many different kinds of seeds that it would take many more experiments to determine what purpose the cotyledons serve. But much discussion took place about transferring the findings of this experiment to other seeds. In fact, it raised much interest in the structure and adaptation of seeds.

Reporting the solution.[4] There are many ways of reporting what was done in solving a problem: reports can be given orally, graphic descriptions can be displayed in murals, and so on. One way of reporting in science has been to use the four headings: Purpose, Method, Observations, and Conclusions. These headings are useful for recording clearly what has been done. But they are not always useful for describing the thinking and experimenting that needs to be recorded while the problem is being

4. See "Reporting Skills" in Ontario Ministry of Education, *Education in the Primary and Junior Divisions* (Toronto: Ministry of Education, Ontario, 1975), pp. 97-98.

tackled. The rough working notes made during the problem-solving stages should be distinguished from the finished report, which uses headings like those above and includes carefully prepared tables, graphs, and drawings. The reporting need not become very technical, however. Primary children, of course, will use simple statements like "What do I want to find out?", "What did we do?", and "What did we find?".

The problem-solving steps outlined above provide a useful general sequence. In problem-solving it is sometimes necessary, however, to return to a previous step. This happens, for example, when the information collected produces a different view of the problem. As well, the individual steps may vary with different kinds of problems or with different teaching strategies. Here are a few variations for some of the steps in the problem-solving sequence presented above.

Identifying the problem. The teacher may want to identify the problem. This may be necessary to save time, because in some cases much discussion is needed to elucidate a problem satisfactorily, so that alternative methods of solution can be suggested. Such discussions may frequently be held with the entire class, with everyone working on the same problem. (For an example, see the sample problem-solving unit in "Planning a Unit of Study" further on in this document.)

Suggesting possible answers. There is usually no problem in obtaining answers when the entire class is involved. So many answers may be obtained, however, that it is difficult to handle them. Hence, the children's thinking should be organized so that particularly productive alternatives emerge, that is, the ones that can be tested. The children may need a second experience with the introductory activity before such alternatives become evident. It is useful to go back to the introductory activity because both the problem and the next step to take can be more clearly defined.

Making a plan for gathering information. In the case study presented above, an experiment was carried out to obtain information. But an experiment may not always be possible. For example, to solve the problem "Why does snow last longer in the spring on the south side of the road?", it is necessary to investigate whether the problem has some pattern and what the possible causes might be.

The problem of determining the approximate number of plants of a particular kind in a woodlot requires a different strategy. Students might calculate the number of plants in a small area and then extrapolate from it to determine the approximate number of plants in the whole woodlot.

When a single event such as the death of a guinea pig (something that might occur in a Primary class) has occurred, an experiment or survey is not required. Rather, it is necessary to gather information in a kind of case history by reviewing the recent life of the guinea pig in order to determine the cause of its death.

Thus, the problem-solving process will vary according to the kind of problem considered and the strategy the teacher wishes to pursue. It must be recognized, however, that where a teacher presents the problem and the plan, all that is left of the problem-solving process for the students is to carry out the directions provided, with little opportunity to develop their own thinking. This is a questionable practice if one is trying to help children improve their skill in solving problems. Children will become better problem-solvers if they are allowed to practise the variety of skills themselves - if possible, on problems that they have developed.

The thinking skills described at the beginning of this section are used in the problem-solving process. One can make *inferences* in trying to clarify a problem, *predictions* in interpreting results, and *generalizations* when applying conclusions. *Observing, classifying, seriating,* and *measuring* take place in many operations, such as collecting information from an experiment or a survey and organizing it.

Planning a Unit of Study

1. Growth in Animals – Primary Division

Determining the knowledge to be learned. The planning of a unit of study begins with a statement of the knowledge the students are expected to learn. Growth in animals could be presented as a generalization: Some animals do not resemble their parents at birth and will change completely in form and structure as they grow from birth to adulthood.

Acquiring information. It will then be necessary to determine how this generalization will be fixed in the children's minds, keeping in mind that Primary-Junior children must actually observe numerous examples of a generalization in order to learn it. They can acquire the requisite information in the following ways:

- They can raise mealworms (tenebrio beetles) in the classroom and observe them as they change from larvae to adult beetles.
- They can then raise tadpoles in the classroom and observe them changing into frogs.
- Finally, they can be shown films of a wide range of animals that do not resemble their parents at birth.

Films are recommended because two classroom experiences with animals that do not resemble their parents at birth do not give children enough information to "work on". Since it is often impossible to provide numerous real-life examples, films, videotapes, TV programs, and so on, are helpful aids.

Students should also use and develop measurement skills to expand their perception of the real world. This also gives them the opportunity to practise in a meaningful context the skills they acquire in mathematics. The following are two formats in which students can record their observations.

Give your mealworm (larva) a name.

The name of my mealworm is _____ .

Estimate how many beads long your mealworm is.

I think my mealworm is about _____ beads long.

Measure how many beads long your mealworm is.

My mealworm is _____ beads long.

What colour is your mealworm?

My mealworm is _____ .

Draw a picture of your mealworm in the box and colour it.

Mark off on a piece of string the length of your beetle (adult). Cut off the string and tape it in the box.

What colour is your beetle?

My beetle is _____ .

Draw a picture of your beetle in the box and colour it.

	Egg	Larva (Mealworm)	Pupa	Adult
Size	too small to see	_____ beads long _____ beads wide	_____ beads long _____ beads wide	_____ beads long _____ beads wide
Shape	too small to tell			
Colour				
Number of body parts				
Coverings				
Food				

As children observe the growth changes of animals that do not resemble their parents at birth and that undergo a metamorphosis into adulthood, they should repeatedly be encouraged to note that the most important sign of growth or development is a change in the shape and size of the whole animal, as well as in its parts. They should also understand that the very different-looking shapes they observe are various forms of the same animal.

Processing the new learning. Assuming that it is possible to provide opportunities for children to observe sufficient examples of the generalization to be learned, it is necessary to develop strategies that will encourage them to process this information into personal knowledge. The following are just a few examples of activities that encourage children to represent their observations:

- Children can record their ongoing observations by modelling and/or sketching the animals at each stage of development.
- Some children may be capable of *writing* about their experiences. At the very least, they can begin to label. They might start by following a pattern provided by the teacher ("I used to be a tadpole, but now I am a _____ ") and then develop as many other parallel examples as they can.

Children can be encouraged to classify or group their observations if they are given pictures of animals they have observed and then are asked to sort the pictures according to whether they show adult or young animals.

The following are a few examples of activities that encourage children to seriate their observations:

- The models the children made of various stages in the life cycle of animals are mixed up, and the children then return them to their correct order.
- The sketches the children made of various stages in the life cycle of animals are mixed up, and the children then return them to their correct order.
- Prints of the various stages in the life cycle of animals that the children have observed are provided, and the children put these in order.

Consolidating the new learning. Children should be provided with additional experiences to help them clarify, broaden, and communicate the concepts they are learning. The following are just a few possibilities:

- Teachers can read and discuss with the children books, poems, and songs about animals changing in form and structure as they grow to adulthood. The following poem by Leslie Wilbur is an example:

  Fuzzy wuzzy caterpillar humps a-long, humps a-long, humps a-long.
  Fuzzy wuzzy caterpillar humps a-long, out to see the world.

  Fuzzy wuzzy caterpillar goes to sleep, goes to sleep, goes to sleep.
  Fuzzy wuzzy caterpillar goes to sleep in a warm cocoon.

  Someday you will see a pretty butterfly, butterfly, butterfly.
  Someday you will see a pretty butterfly out to see the world.

- Children should be encouraged to create their own poems about other animals that they are studying, using the poem "Fuzzy Wuzzy Caterpillar" as a model. After the children have discovered that each verse tells of a different stage in the development of a butterfly, the teacher might suggest that the children make up a poem about their mealworms ("Moony Moony mealworm slinks along, slinks along . . . ").
- Books and filmstrips about animal growth can be placed in the library corner and the children permitted to explore these materials on their own. They should then be encouraged to share with the rest of the class the things they discover in these materials. In many schools these activities can be carried out in the school library rather than in the classroom.
- Children can be directed to find a book in the library that tells about an animal that does not resemble its parents when it is born. They should then record what they find out about the way the animal grows and decide how they can share the information with the class (in a poem, story, picture, or booklet). Class charts, such as the ones given below, can be provided for this and other activities. The children record their findings on the class charts, putting their names beside the information they have added so that they can be called on to tell the class about the animal.

Animals that do not resemble their parents at birth

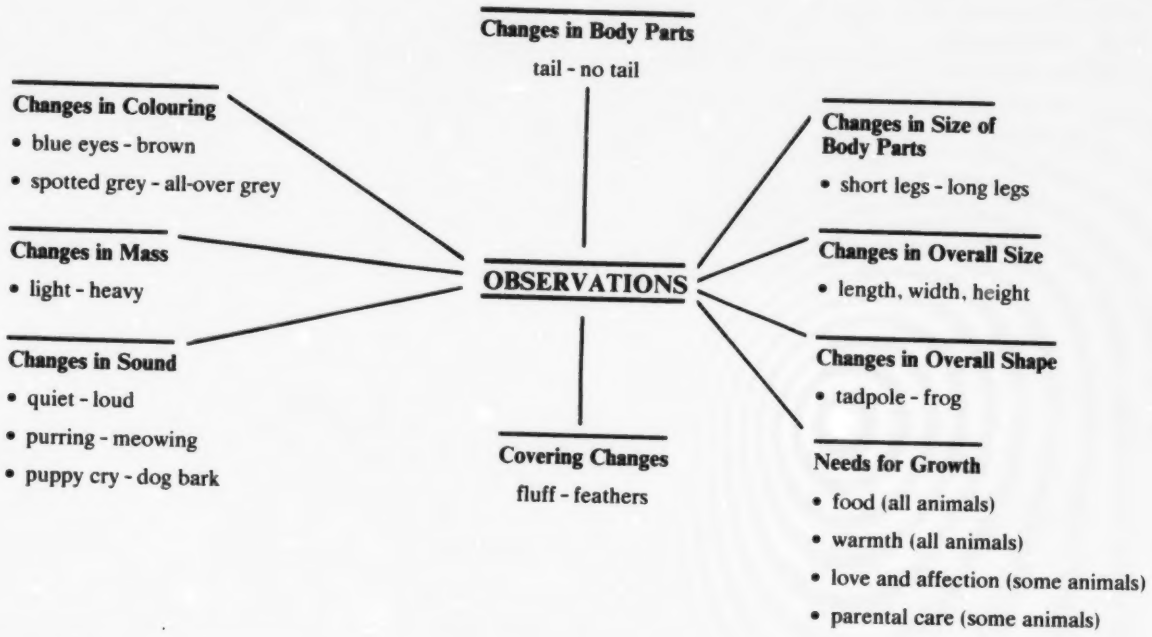
Offspring	Adult	Pupil's name
tadpole	frog	Jack
mealworm	beetle	Sue

Animals that do resemble their parents at birth

Offspring	Adult	Pupil's name
kitten	cat	Gino
chick	chicken	Carol
cub	lion	Ange
fawn	deer	Sam

- Books, poems, filmstrips, and so on, can all be used by the teacher to broaden the children's understanding and to stimulate discussion that encourages the children to organize their thinking. It makes little difference what kinds of material are used. What is important is that the children be given opportunities to organize their experiences in ways that are relevant to the knowledge they must grasp.

Related ideas. In addition to the generalization about growth examined ("Some animals do not resemble their parents at birth . . . "), many related objectives and observations might be pursued by Primary children. The following chart illustrates a group of these. Note the kinds of related observations that the children could make.


OBSERVATIONS
Changes in Body Parts
tail - no tail
Changes in Colouring
• blue eyes - brown
• spotted grey - all-over grey
Changes in Mass
• light - heavy
Changes in Sound
• quiet - loud
• purring - meowing
• puppy cry - dog bark
Changes in Size of Body Parts
• short legs - long legs
Changes in Overall Size
• length, width, height
Changes in Overall Shape
• tadpole - frog
Covering Changes
fluff - feathers
Needs for Growth
• food (all animals)
• warmth (all animals)
• love and affection (some animals)
• parental care (some animals)

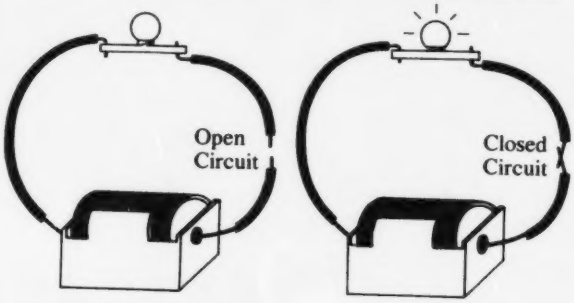
II. Batteries and Bulbs - Junior Division

This topic has been taught in many classrooms and in many different ways. If taught Socratically, with the students having little or no opportunity to manipulate materials, the lesson becomes confusing and content-oriented; the students simply memorize their notes. Similarly, if the topic is taught completely by open-ended discovery, the elements of knowledge are lost, and the students experience little skill development. Thus, the learning process outlined earlier in this document helps order the teacher's task of turning information into personal knowledge.

Determining a concept to be learned. First, a concept to be taught should be chosen. For example, the concept of a circuit could be taught: An electric circuit is a path of wires connected to a source of electricity (a dry-cell battery) into which an electrical device (a lamp) is inserted in such a way that it works. When a lamp lights up, the circuit is closed. When a wire is disconnected and the lamp does not light up, the circuit is open.

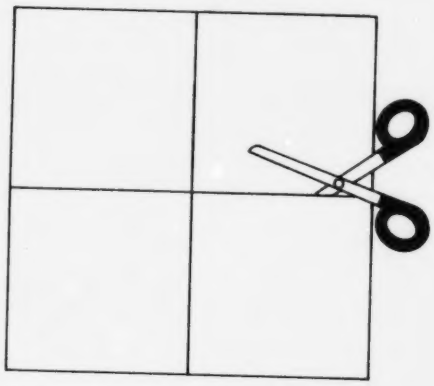
Acquiring information. Once the teacher has decided which concept to teach, he or she must decide how to present it to the class. For example, students can acquire the requisite information by the following sequence of experiments:

- They can use these items to try to make a lamp light: one 15-cm piece of insulated wire stripped at each end, one D-size dry-cell battery, and one 2-V electric lamp. These objects can be used to explain the concept of an electric circuit and the reason why it is called a *circuit*.
- Next, they can make a simple circuit using a bulb, a bulbholder, a dry-cell battery, a battery holder, and three 15-cm pieces of insulated wire stripped at the ends. They can then create open and closed circuits, as shown in the illustrations below.



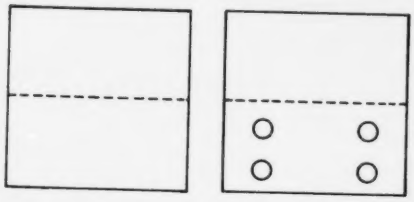
- Finally, they can experiment with circuit boards constructed according to the following directions.

Step 1. Cut four equal rectangles from a 22-cm x 30-cm sheet of construction paper.

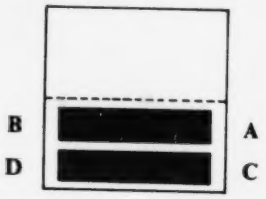


Step 2. Fold each rectangle in half.

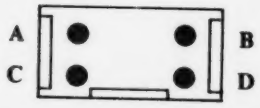
Step 3. Punch four holes and label them.



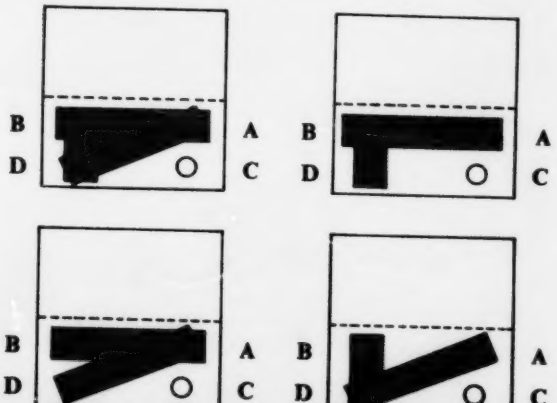
Step 4. Turn the paper over. Cut foil in strips of 1 cm x 9 cm each and tape them to the paper.



Step 5. Fold the boards in half to cover the foil and seal the edges with tape.



These patterns could also be used:



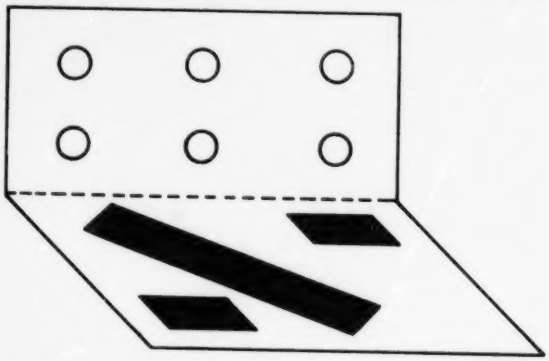
The students can use the simple circuits they have contructed for the previous experiment to observe what happens when the two wires used to open and close the ciruit are connected to any two points on the circuit board. All of the points should be tested in this way, and the results recorded in a chart:

Connections Observations	AB	AC	AD	BC	BD	CD
Bulb lights. (closed circuit)	X					X
Bulb does not light. (open circuit)		X	X	X	X	

The children can be asked to use their observations to suggest how the points beneath the construction paper are joined by the strips of foil. For example, a student might suggest that the connections are A to B and C to D because, when the points were tested, AB and CD made the lamp light, thus indicating that something was connecting these points. In this way the children use their observations to make inferences about the connections they cannot observe directly. These inferences must be confirmed, so the circuit boards should be opened to verify the inferences. Note that some of the alternative circuit-board patterns shown (see bottom of previous page) will yield observations leading to inferences that are incorrect even though they are reasonable.

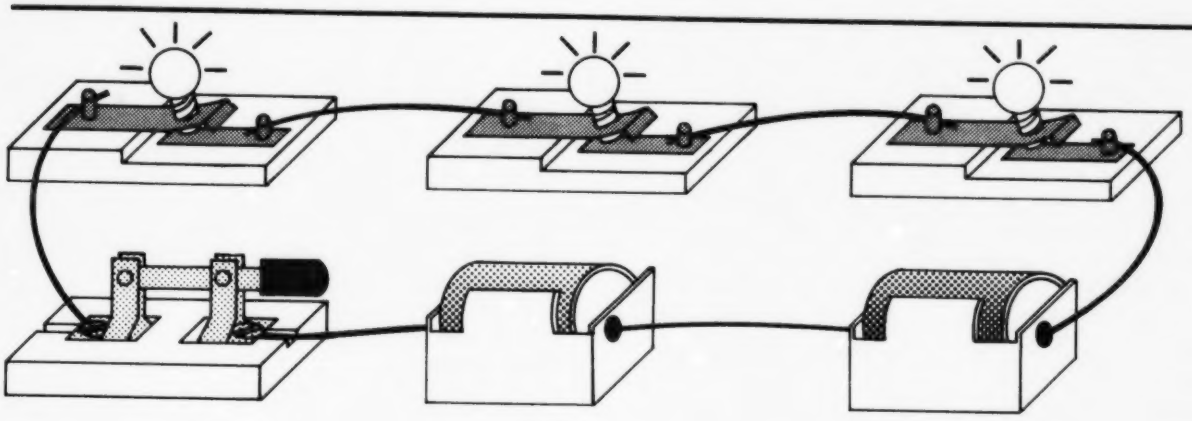
Processing the new learning. Now that the children have had three experiences with open and closed circuits, they can process into personal knowledge the information they have acquired by continuing their investigations in the following ways:

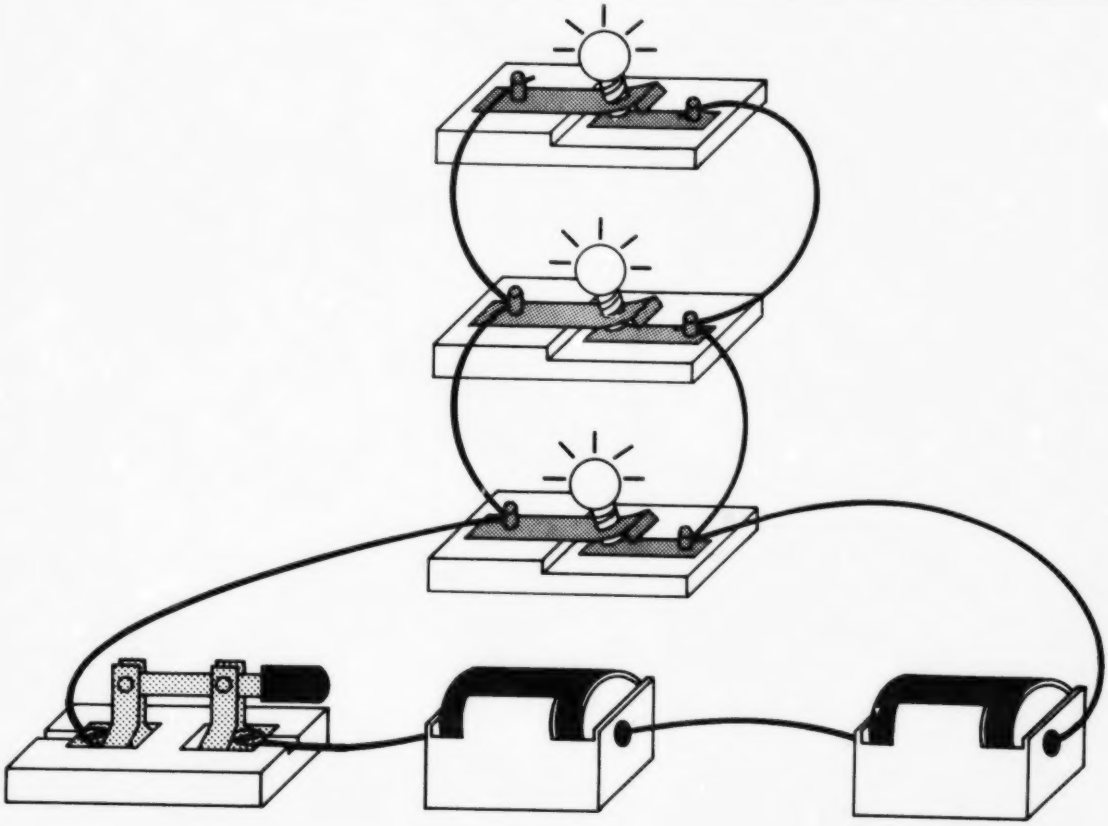
- They can design circuit boards with six (and then eight) points and test their classmates to see if they can infer the pattern of connections.



- They can devise a switch for each circuit so that it can be opened or closed.

- Working in a group of three pairs (six children in a group), they can use their combined materials to make the circuits below and then identify each circuit as a *series* or *parallel* circuit after discussing the meaning of these words.

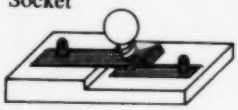
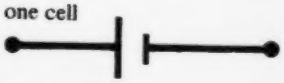
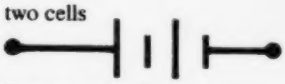
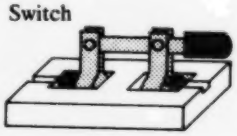
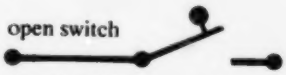
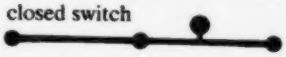




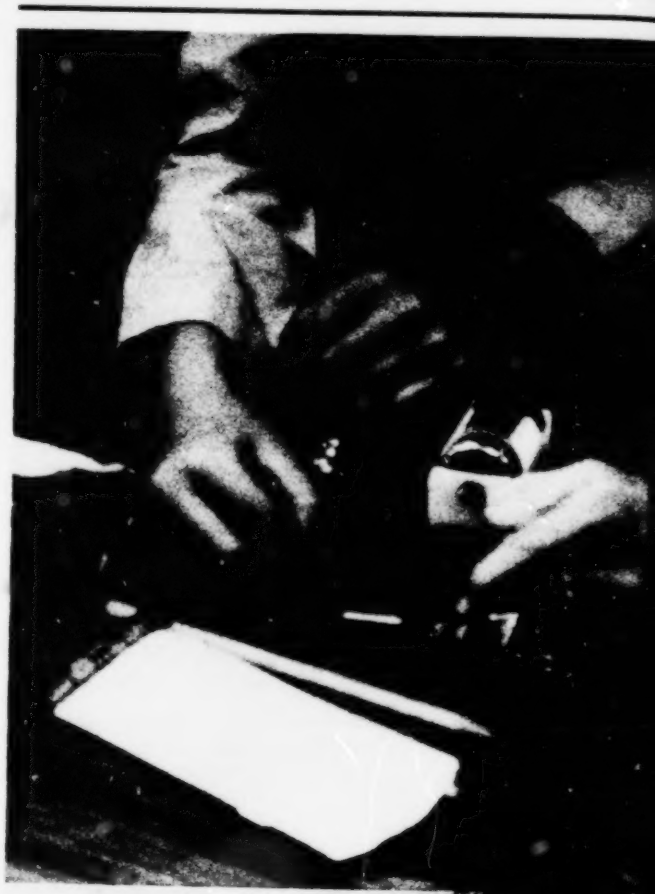
- They can write descriptions, complete with diagrams, of *open circuit, closed circuit, series circuit,* and *parallel circuit.* Each description should include information on how to construct the circuit and what to observe.

Consolidating the new learning. The children should now be given other opportunities to clarify, broaden, and communicate the new concepts. Here are some suggestions:

- They can use symbols to diagram the circuits they have made. They should discuss the advantages of using symbols instead of drawing the actual objects.

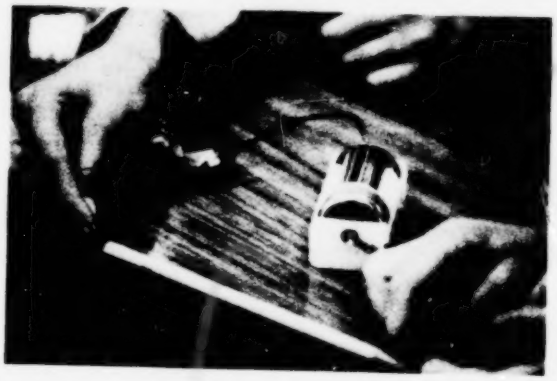
Object	Symbol
Lamp in Socket 	Lamp
Dry Cell	one cell 
	two cells 
	Longer vertical line represents end of cell with protruding centre post.
Switch 	open switch 
	closed switch 

- They can use the symbols to diagram the circuit of the classroom lights. Although they know where the switches and light fixtures are, they will have to infer where the wires are located in the walls and ceiling. (The electrical source is, of course, located outside the classroom.)

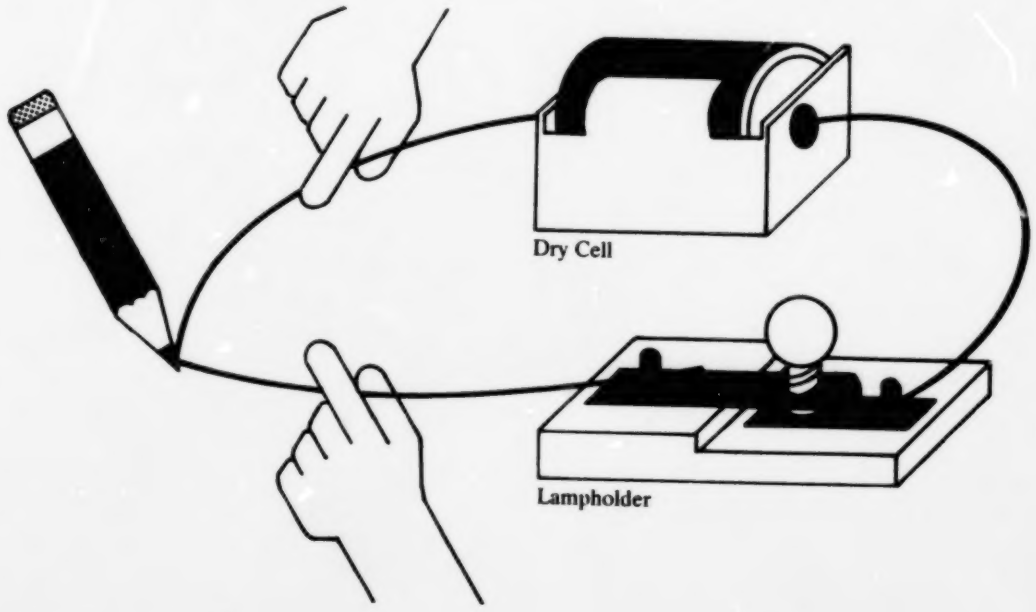


- In pairs, the children can use the simple circuits they have created to discuss how electricity flows in a circuit and what kinds of material will conduct electricity. They can experiment with as many materials in the classroom as possible to find out which ones will conduct electricity (conductors) and which ones will not (non-conductors). They can devise these experiments themselves and then record their observations in a chart:

Materials tested	Bulb lighted.	Bulb did not light.
Pencil (lead)		
Paper clip		
Wooden ruler		
Textbook		
Crayon		
Toothpick		
Aluminium foil		



From their observation charts they can be asked to infer which other materials are conductors or non-conductors. They can also be asked to develop hypotheses. For example, the children might decide that "all metals are conductors" or that "materials that are soft will not conduct electricity". The first of these sample hypotheses can be substantiated by additional experiments with many forms of metals and a generalization made, while the second can be disproved by the discovery of one material, such as steel wool, that is both soft and a conductor of electricity. Thus, the second hypothesis must be changed or dismissed. In this way they can develop their ability to think scientifically.



III. A Problem-solving Approach to "Batteries and Bulbs"

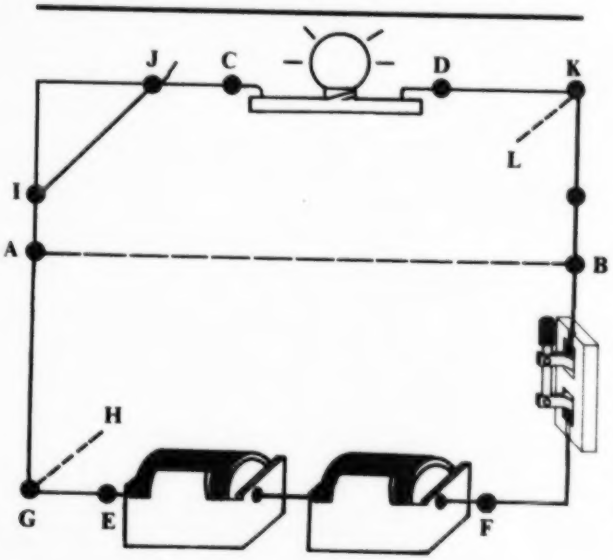
As stated earlier in this document, a problem-solving approach promotes independent learning and helps children make informed and rational decisions. The preceding sample unit of study could be conducted through a problem-solving approach. The following activity, which is an extension of the concepts in electricity already presented, has been included to illustrate how this can be done.

The activities used initially to teach the stages of problem-solving should be teacher-directed, as in the examples that follow; they should, however, involve the children as much as possible. Once children know the steps, teachers should direct problem-solving only when a new concept, generalization, skill, or technique must be taught.

Starting inquiry by introducing an activity. In their introductory activities the students have been building and observing a variety of simple circuits (open, closed, parallel, and series). The teacher can use the chalkboard and a real model of a circuit to review these activities.

Identifying a problem (by the teacher). The teacher can introduce the problem, "Can you affect the light by adding a wire to the circuit?" A discussion about possible places where the wire might be connected to the circuit will help to stimulate student inquiry and clarify the problem.

The students can then draw a labelled diagram of the possible alternative positions for the wire.



Suggesting possible answers. Here are some suggestions students might make for placing the wire and the possible results:

Wire placement	What might happen?
AB	Light won't work.
CD	Light will dim.
EF	Light won't work.
GH	Light will dim.
IJ	No change.
KL	Bulb will still light.

Making a plan to gather information. The students collect the materials needed for their experiment: two D-size batteries, two battery holders, one 2-V bulb, one bulbholder, one switch, three pieces of 15-cm bare copper wire, and one 20-cm piece of insulated copper wire bared at both ends. They now construct an open circuit and check to make sure that the bulb lights when the switch is closed. They then use a piece of copper wire to connect, in turn, points A and B, C and D, E and F, G and H, I and J, and K and L, closing the circuit at the switch each time. In each case they observe and record what happens. The test is repeated two more times for each of the six different connections.

Collecting and organizing the information. The information can be collected and organized in a table:

Points joined	What happened to the light? Did anything else happen?
1. AB	Light went dim.
2. AB	Light went dim.
3. AB	Light went dim.
1. CD	Light went dim.
2. CD	Light went dim.
3. CD	Light went dim.
— —	— —
— —	— —
— —	— —
1. KL	No change.
2. KL	No change.
3. KL	No change.

Interpreting the results. The students should ask themselves questions like these:

- Did we get the answers we suggested at the beginning of the experiment?
- Did the results vary?
- In which locations of wire placement did we get the same result?
- What is the answer to the problem, "Can you affect the light by adding a wire to the circuit?"

Drawing conclusions. The students might conclude that, using a bare copper wire, they can make the light dim by connecting the circuit wire leading from the battery to the bulb to the circuit wire leading from the bulb back to the battery. The teacher can then introduce the term *short circuit* to describe what the students have done.

Applying the conclusions. This activity should be performed by the teacher, who should use the same type of circuit but with a 6-V battery or four 1.5-V batteries in a series as the power source and a 6-V bulb.

To create the short circuit, connect a suitable length of pipe cleaner to the bulbholder terminals. (The pipe cleaner should be bared at both ends with the aid of a flame and all material removed from between the wires. To ensure contact, clean both bared ends with sandpaper.) Have the pupils predict what will happen when the circuit switch is closed.

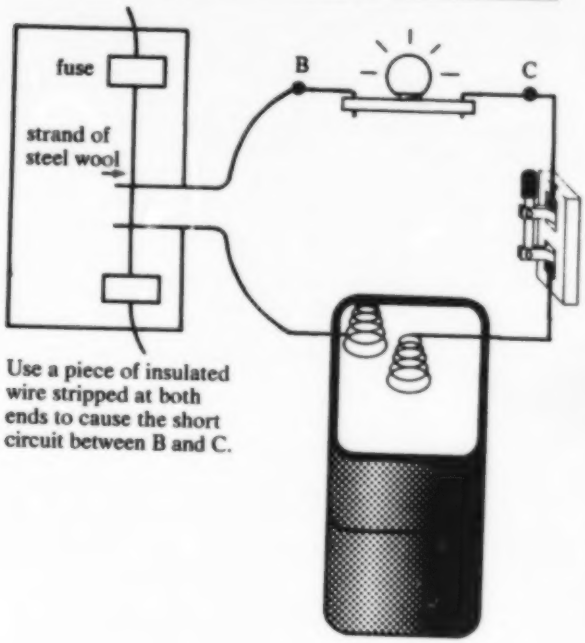
Note: The pipe cleaner will become hot and will smolder, so a suitable work area should be chosen. Children should be cautioned. At the conclusion of the activity, the circuit should be opened at the switch and allowed to cool before it is dismantled.

The teacher can discuss and compare the students' observations with the findings from the previous activity. The discussion could include such questions as:

- What would happen if a short circuit occurred in a household circuit? In a car?
- How can a device be used to protect a circuit from being short-circuited?

The students can also be asked to find out what information the local fire department has on short circuits and fires.

Any of these applications of the conclusions can be the starting point for solving a new problem, for example: "What material can be used for a fuse to protect an electric circuit in case of a short circuit?" The following diagram (see top of next page) illustrates one possible experiment to solve this problem.



Use a piece of insulated wire stripped at both ends to cause the short circuit between B and C.

Note: This activity should be performed by the teacher. Because steel wool will burn if placed on both terminals of a 6-V battery, all steel wool not being used should be kept in the container away from the battery.

A complete unit on electricity could be developed by following these steps based on the learning process outlined previously:

- Select a group of related concepts.
- Plan experiences that will introduce the related concepts to the children.
- Plan activities that will encourage the children to process the information they acquire.
- Plan activities involving communication and vicarious experiences that will give the children a deeper understanding of the new concepts.
- Evaluate what the children have learned.

At each stage of planning, the teacher should consider what effects, attitudes, values, or learning the children's experiences will foster and whether these are adequate.

Keeping Parents Informed

It is important that parents be informed of their children's progress. Periodic meetings with parents should stress the positive aspects of the child's work. The following are some things to consider when discussing with parents the child's progress in developing science skills:

- *Observing.* Can the child see qualities within a specific science situation (likenesses or differences of structure, changes, similarities and/or dissimilarities)? Does this initial step in the scientific process lead him/her to questions and/or directions for further investigation?
- *Classifying.* What stage of development has the child reached in classifying objects and/or ideas in terms of (a) common attributes and/or qualities, (b) colour, (c) simple shapes, (d) small numbers, (e) motion? Does the child reclassify items when new facts are perceived? As the child develops, does he/she use more than one attribute or quality at the same time? Can the child generalize qualities and/or attributes?
- *Recording.* This is basic to the scientific method. Does the child use first, second, and so on, as organizers in his/her pictorial, oral, or written descriptions? Does the child indicate up-down, side-to-side relationships? Use diagrams? List the sources of his/her information? Use new words in recording original ideas? Record material in a logical sequence with techniques appropriate to his/her level of experience?
- *Measuring.* Can the child compare objects as to length, heaviness, hardness, colour, quantity, speed, and so on? Can he/she use arbitrary units of measurement (markers, string, tiles)? Can he/she use standard units and equipment to measure time, mass, length, area, and volume?
- *Predicting.* Can the child analyse logically an outcome with or without complete knowledge of the subject? Imagine things that cannot be seen, such as air? Remember past experiences and predict on this basis rather than guess? Use the predictions of others? Make specific predictions based on specific data?
- *Communicating.* Does the child listen to directions? Show others what he/she has constructed or arranged? Use new words in communicating his/her own ideas? Use diagrams to show the relative position of objects?
- *Explaining.* Can the child express a logical relationship in scientific conclusions? Look at or use simple diagrams? Make his/her own diagrams a part of an explanation? Use models as a tangible representation of objects or events?

Resources

A. Suggested References for Teachers

Esler, William K. *Teaching Elementary Science.* Belmont, Calif.: Wadsworth, 1977.

Fullan, M., and Park, P. *Implementing Curriculum Change.* Toronto: Ministry of Education, Ontario, 1981.

Good, Ronald G. *How Children Learn Science.* New York: Macmillan, 1977.

Greaves, D. G., and Williams, P. *Canadians' Contribution to Science.* Toronto: Toronto Board of Education, 1980.

Harland, Jean D. *Science Experiences for the Early Years.* Columbus, Ohio: Charles E. Merrill, 1976.

Harlen, Wynne; Black, Paul; and Johnson, Sandra. *Science in Schools - Age 11: Report No. 1.* London Department of Education and Science, 1981.

Mumby, H.; Orpwood, G.; and Russell, T. *Seeing Curriculum in a New Light.* Toronto: OISE Press, 1980.

Nickelsburg, J. *Nature Activities for Early Childhood.* Don Mills: Addison-Wesley, 1976.

Ontario, Ministry of Agriculture and Food. *Ontario, Animals for Research Act.* Toronto: Queen's Printer, 1968-69.

Ontario, Ministry of Education. *Clothing and Shelter.* Toronto: Ministry of Education, Ontario, 1981.

_____. *Clothing, Shelter, and Energy.* Toronto: Ministry of Education, Ontario, 1980

_____. *Eating and Energy: A Part of Every Day.* Toronto: Ministry of Education, Ontario, 1980.

_____. *Food and Human Energy.* Toronto: Ministry of Education, Ontario, 1980.

_____. *Transportation and Energy.* Toronto: Ministry of Education, Ontario, 1980.

_____. *Water and Energy.* Toronto: Ministry of Education, Ontario, 1980.

_____. *We Really Care About Water and Air!* Toronto: Ministry of Education, Ontario, 1981.

_____. *What Is Energy?* Toronto: Ministry of Education, Ontario, 1981.

Robinson, F. G.; Rickle, J.; and Brison, D. W. *Inquiry Training: Fusing Theory and Practice.* Profiles of Practical Education, no. 4. Toronto: Ontario Institute for Studies in Education, 1972.

Trojcak, Doris A. *Science With Children.* New York: McGraw-Hill, 1979.

B. Science Books for Children

Primary Division

Abisch, Roz. *Around the House That Jack Built.* New York: Parents' Magazine Press, 1972.

Arnold, Caroline. *Five Nests.* New York: Dutton, 1980.

Baylor, Byrd. *If You Were a Hunter of Fossils.* New York: Scribner's, 1980.

Clery, Val. *A Day in the Woods.* Toronto: Greey de Pencier, 1978.

Cochrane, Orin, ed. Reading Experiences in Science Series (8 books). Winnipeg: Peguis, 1980.

Dabcovich, L. *Follow the River.* New York: Dutton, 1980.

Freeman, Mae. *The Real Magnet Book.* New York: Scholastic Book Services, 1967.

Freschet, Berniece. *The Watersnake.* New York: Scribner's, 1979.

Gibbons, Gail. *Locks and Keys.* New York: Crowell, 1980.

Gutnik, Martin J. *How Plants Are Made.* Chicago: Children's Press, 1976.

_____. *How Plants Make Food.* Chicago: Children's Press, 1976.

_____. *What Plants Produce.* Chicago: Children's Press, 1976.

Henley, Karyn. *Hatch!* Minneapolis: Carolrhoda Books, 1980.

Jaspersohn, William. *How the Forest Grew.* New York: Greenwillow, 1980.

Lexau, Joan M. *The Spider Makes a Web.* New York: Hastings House, 1979.

McKeen, Martha. *Sunflower.* New York: Dodd, Mead, 1980.

McNulty, Faith. *How to Dig a Hole to the Other Side of the World.* New York: Harper, 1979.

Michel, A. *Little Wild Lion Cub.* New York: Pantheon, 1980.

Selsam, Millicent E. *Night Animals.* New York: Four Winds, 1980.

_____. *Questions and Answers About Ants.* New York: Scholastic Book Services, 1967.

Sheehan, Angela. *The Bumblebee.* New York: Franklin Watts, 1976.

Showers, Paul. *No Measles, No Mumps for Me.* New York: Crowell, 1980.

Yolen, Jane. *All in the Woodland Early: An ABC Book.* Cleveland: Collins, 1979.

Junior Division

Aliki. *Mummies Made in Egypt.* New York: Crowell, 1979.

Asimov, Isaac. *How Did We Find Out About* Series. New York: Walker.

Aylesworth, Thomas. *Storm Alert: Understanding Weather Disasters.* New York: Messner, 1980.

Blumberg, Rhoda. *The First Travel Guide to the Moon: What to Pack, How to Go, and What to See When You Get There.* New York: Four Winds, 1980.

Branley, Franklyn M. *The Electromagnetic Spectrum: Key to the Universe.* New York: Crowell, 1979.

Brooks, Bill. *Wildlife in Canada in Colour.* Willowdale, Ont.: Hounslow, 1976.

Budlong, Ware, and Gleitzer, Mark H. *Experimenting With Seeds and Plants.* New York: Putnam's, 1970.

Burns, Sheila. *Allergies and You.* New York: Messner, 1980.

Cole, Joanna. *A Chick Hatches.* New York: Morrow, 1976.

_____. *A Frog's Body.* New York: Morrow, 1980.

Dean, Annabel. *Up, Up, And Away! The Story of Ballooning.* Philadelphia: Westminster, 1980.

Elting, Mary. *Dinosaur Mysteries.* New York: Platt and Munk/Grosset, 1980.

Ford, Barbara. *Why Does a Turtle Live Longer Than a Dog?* New York: Morrow, 1980.

Freedman, Russell. *Tooth and Claw: A Look at Animal Weapons.* New York: Holiday, 1980.

Freeman, Mae, and Freeman, Ira. *Arrow Book of Space.* New York: Scholastic Book Services, 1976.

Gibbons, Gail. *Locks and Keys.* New York: Crowell, 1980.

Graham, Frank, Jr., and Graham, Ada. *The Careless Animal: Nine Ecological Detective Stories.* New York: Doubleday, 1975.

Haines, K. *Natural and Synthetic Poisons.* New York: Morrow, 1978.

Herbert, Don. *Mr. Wizard's Supermarket Science.* New York: Random House, 1980.

Hess, Kilo. *Listen to Your Kitten Purr.* New York: Scribner's, 1980.

Hewett, Joan. *Watching Them Grow: Inside a Zoo Nursery.* Boston: Little, Brown, 1979.

Hinshaw, Dorothy. *The Lives of Spiders.* New York: Holiday, 1980.

Holling, C. *Minn of the Mississippi.* Boston: Houghton Mifflin, 1951.

_____. *Pagoo.* Boston: Houghton Mifflin, 1957.

_____. *Seabird.* Boston: Houghton Mifflin, 1948.

Hutchins, Ross E. *The Cicada.* Reading, Mass.: Addison-Wesley, 1971.

Jonas, Jane J. *Spaces, Shapes, and Sizes.* New York: Crowell, 1980.

Kalina, Sigmund. *Air, the Invisible Ocean.* New York: Scholastic Book Services, 1973.

Knight, David. *Silent Sound: The World of Ultrasonics.* New York: Morrow, 1980.

Lawrence, R. D. *Paddy.* New York: Knopf, 1977.

Mccauley, David. *Castle.* Boston: Houghton Mifflin, 1977.

_____. *Cathedral.* Boston: Houghton Mifflin, 1973.

_____. *City.* Boston: Houghton Mifflin, 1974.

_____. *Pyramid.* Boston: Houghton Mifflin, 1975.

McFall, Christie. *Wonders of Dust.* New York: Dodd, Mead, 1980.

McKeever, Katherine. *A Family for Minerva.* Toronto: Greey de Pencier, 1980.

Mason, Bill. *When the Wolves Sang.* Toronto: Greey de Pencier, 1980.

May, Charles P. *A Book of Canadian Animals.* Toronto: Macmillan, 1975.

_____. *A Book of Canadian Birds.* Toronto: Macmillan, 1975.

_____. *A Second Book of Canadian Animals.* Toronto: Macmillan, 1977.

Meyers, Susan. *The Truth About Gorillas.* New York: Dutton, 1980.

Moche, Dinah. *What's Up There? Questions and Answers About Stars and Space.* New York: Scholastic Book Services, 1975.

Munroe, Esther. *Sprouts to Grow and Eat.* Brattleboro, Vt.: Stephen Greene, 1974.

Patent, Dorothy H. *Horses and Their Wild Relatives.* New York: Holiday, 1981.

_____. *Hunters and the Hunted: Surviving in the Animal World.* New York: Holiday, 1981.

_____. *Raccoons, Coatimundis and Their Family.* New York: Holiday, 1979.

Porell, Bruce. *Digging the Past: Archeology in Your Own Back Yard.* Reading, Mass.: Addison-Wesley, 1979.

Poynter, M. *Volcanoes: The Fiery Mountains.* New York: Messner, 1980.

Pringle, Lawrence. *Chains, Webs and Pyramids: The Flow of Energy in Nature.* New York: Crowell, 1975.

Rau, Margaret. *The Grey Kangaroo at Home.* New York: Knopf, 1978.

Ross, Judy. *Zoo Book* Series. Lexington, Mass.: D. C. Heath, 1979.

Salvadori, Mario. *Building: The Fight Against Gravity.* New York: Atheneum, 1979.

Selsam, Millicent E. *Eat the Fruit, Plant the Seed.* New York: Morrow, 1980.

_____. *Play With Plants.* New York: Morrow, 1978.
_____. *Popcorn.* New York: Morrow, 1976.

_____. *Up, Down and Around: The Force of Gravity.* Garden City, N.Y.: Doubleday, 1977.

Silverstein, Alvin. *Mice, All About Them.* New York: Lippincott, 1980.

Simon, Seymour. *Mirror Magic.* New York: Lothrop, 1980.

Spivak, Michael, ed. *What Will They Think of Next?* Toronto: McClelland and Stewart, 1979.

Stein, Sara. *The Science Book.* New York: Workman, 1980.

Taylor, G. Jeffrey. *A Close Look at the Moon.* New York: Dodd, Mead, 1980.

Walther, Tom. *A Spider Might.* New York: Scribner's, 1978.

Weiss, Marvin. *How to Be an Inventor.* New York: Crowell, 1980.

Wexler, Jerome. *Secrets of the Venus's Fly Trap.* New York: Dodd, Mead, 1981.

Wilson, Ron. *How Plants Grow.* New York: Larousse, 1980.

Woods, S. E. *The Squirrels of Canada.* Ottawa: National Museum of Natural Sciences, 1980.

Woodside, Dave. *What Makes Popcorn Pop?* New York: Atheneum, 1980.

C. Periodicals

Chickadee. Young Naturalist Foundation, 59 Front Street East, Toronto, Ontario M5E 1B3.

Crucible. Science Teachers' Association of Ontario, Box 975, Postal Station A, Scarborough, Ontario M1K 5E4.

National Geographic World. National Geographic World, Department 00782, 17th and M Streets, N. W., Washington, D. C. 20036.

Owl. Owl Magazine, 59 Front Street East, Toronto, Ontario M5E 1B3.

Ranger Rick's Nature Magazine. National Wildlife Federation, 1412 16th Street, N. W., Washington, D. C. 20036.

Science and Children. National Science Teachers' Association, 1742 Connecticut Avenue, N. W., Washington, D. C. 20009.

Validators:

W. A. Allen, Principal, M. A. Wittick Junior Public School, East Parry Sound Board of Education

Sheila Allin, Environmental Studies Consultant, Peel Board of Education

Les Asselstine, Environmental Studies Consultant, Waterloo County Board of Education

Ghislaine Auger, Lamoureaux Separate School, Ottawa Roman Catholic Separate School Board

Rodney Bain, Associate Professor, Faculty of Education, the University of Western Ontario

K. Bennett, Education Officer, Elementary Education Branch, Ministry of Education

C. E. Birchard, Supervisor, Curriculum, Bruce County Board of Education

A. Biro, Education Officer, Central Ontario Regional Office, Ministry of Education

R. C. Blackwell, Education Officer, Elementary Education Branch, Ministry of Education

W. Brown, Director of Education, Bruce-Grey County Roman Catholic Separate School Board

R. Carter, Teacher, Field Studies Centre, Etobicoke Board of Education

J. H. Christopher, Co-ordinator of Science, North York Board of Education

J. G. Davis, Education Officer, Elementary Education Branch, Ministry of Education

C. N. Eadie, Consultant, Pure/Applied Science, Stormont, Dundas, and Glengarry County Board of Education

Don Garratt, Co-ordinator of Science, Scarborough Board of Education

G. A. George, Education Officer, Elementary Education Branch, Ministry of Education

D. M. Hall, Education Officer, Northwestern Ontario Regional Office, Ministry of Education

M. Harrison, Science Consultant, Ottawa Board of Education

R. D. Hember, Co-ordinator of Science, Peel Board of Education

Roy C. James, Environmental Studies/Mathematics Consultant, Windsor Roman Catholic Separate School Board

M. L. Johnson, Environmental Studies Co-ordinator, London and Middlesex County Roman Catholic Separate School Board

B. A. Johnston, Education Officer, Elementary Education Branch, Ministry of Education

R. David Joyce, Assistant Co-ordinator of Science, East York Board of Education

Leslie P. Kovacs, Teacher, William Beatty Public School, West Parry Sound Board of Education

F. H. Lemieux, Education Officer, Midnorthern Ontario Regional Office, Ministry of Education

M. McKinley, Primary French Immersion Consultant, Ottawa Board of Education

John R. McNally, Principal, St. Francis Separate School, Lakehead District Roman Catholic Separate School Board

Sylvia McPhee, Education Officer, Special Education Branch, Ministry of Education

Carol Maher, Environmental Studies Consultant, Dufferin-Peel Roman Catholic Separate School Board

Madeleine Major, Curriculum Consultant, Stormont, Dundas, and Glengarry County Roman Catholic Separate School Board

Doug Paul, Program Leader, North York Board of Education

John Pettit, Science Co-ordinator, Halton Board of Education

A. Robbins, Education Officer, Elementary Education Branch, Ministry of Education

William R. Roper, Science Consultant, London Board of Education

Judy Ruetters, Consultant, K-8 Science and Environmental Studies, Ottawa Board of Education

Sylvia St. Jean, Teacher, St. Charles Separate School, Timmins District Roman Catholic Separate School Board

Bill Shugan, Head of Science, Hamilton Board of Education

M. Joyce Smith, Science Resource Teacher, Frontenac-Lennox and Addington County Roman Catholic Separate School Board

H. A. Stevenson, Associate Dean (Academic), Althouse College, the University of Western Ontario

Ken Stief, Co-ordinator of Science, North York Board of Education

R. H. Stinson, Head, Ontario Institute for Studies in Education, Western Ontario Centre

J. Strever, Teacher, Fred C. Cook Public School, Simcoe County Board of Education

Julie Tuepah, Vice-Principal, St. Isidore Separate School, Carleton Roman Catholic Separate School Board

Rosemary M. Webster, Teacher, Cyril Varney Public School, Sudbury Board of Education

Daniel P. Wentworth, Science Consultant, Hamilton Board of Education

David A. White, Science and Environmental Studies Consultant, Elgin County Board of Education

Ken C. Willson, Teacher, Princess Elizabeth Senior Public School, London Board of Education

Audrey E. Wilson, Outdoor Education Consultant, Northumberland and Newcastle Board of Education

Margaret Winckel, Principal, George Vanier Public School, Sudbury Board of Education

David Woodhall, Senior Consultant, Waterloo County Board of Education

Barbara Worth, Junior/Intermediate Resource Teacher, Scarborough/East York Region, Metropolitan Separate School Board